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Original Research Paper

Architecture

COMPARATIVE ANALYSIS OF ENERGY DEMAND IN 3 KINDERGARTENS IN NEUQUÉN AND ITS IMPROVEMENT.

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ABSTRACT With European funding, energy audits were carried out in municipal buildings in the city of Neuquén with the aim of determining their level of energy efficiency and feasibility of improvement through their energy rehabilitation. It was surveyed, energy consumption in winter and summer was taken, hygrothermal comfort was recorded, and energy indicators were developed. Results obtained in a sample of three kindergartens built between 1970 and the present are presented.

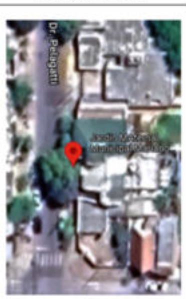
KEYWORDS : energy efficiency, municipal buildings, education.

INTRODUCTION

Within the framework of the R+D projects 183 Management and certification of sustainable and energy-efficient buildings and Euroclima+: Energy-efficient and sustainable municipal buildings, they made it possible to finance energy audits in several municipalities in the country. In this case, 6 municipally managed buildings in the City of Neuquén were audited, of which three of them will be analyzed in this paper. In all cases, kindergartens from three different historical moments of the '60s, '70s and '90s that have diverse characteristics in image and materiality and similarities in the use of energy.

Thus, the "Eva Perón" Kindergartens at 300 Candelaria Street, "Mariano Moreno" at Dr Pelagatti and Domuyo Street and "Eluney" at 1600 Belgrano Street were monitored; located in the urban area of the city.

Table 1: Satellite And Façade View Of Buildings. Source: Google Maps And Own.

Municipal Kindergarten "Eva Perón"	Municipal Nursery School "Mariano Moreno"	Municipal Kindergarten "Eluney"
		
		

METHODOLOGY

Visits are made in summer (February) and winter (July) of 2022 in order to install the instruments that are left operating for a week in order to monitor the interior and exterior hygrothermal behavior along with the consumption of electricity and natural gas. HOBO U23-001 micro data acquirers with weather protection were used; model U12-012; model U10-003 and model UX100-003. A Testo model 815 thermal imaging camera. A distance meter, a 10m tape measure and various tools. The audit team toured the buildings, surveying their main characteristics, accompanied by a municipal official and in each building by their directors. Environmental perception and comfort surveys were carried out among the teachers and employees present. The procedure is an evolution of those that have been carried out since 1986, in what was the IDEHAB FAU UNLP for the Audibaires Project of the Ministry of Energy of the Nation and successive projects up to the present.

With graphic documentation provided by the municipality, a thermal and energy analysis was carried out using an ad-hoc application developed in Excel and using IRAM Standards 11601, 11605, 11604, 11659 and 11900 as a reference (CBF, 2023). The bioclimatic data of the locality are taken from the IRAM 11900/18 Standard, which shows monthly data on average temperatures (°C) and mean solar radiation (W/m2), complemented with data from the NMS. In addition, the information required for the audits is completed (perception surveys, verification of plani-altimetry, consumption measurements, survey of materiality of the envelope, survey of heating and cooling equipment and number of people, thermography, etc.).

Table 2: Monthly Data On Average Temperatures And Solar Radiation By Orientation.

Municipio	Neuquén, Provincia de Neuquén
Edificio	Jardín Maternal Eva Perón
Localidad más cercana en la base de datos:	Neuquen - Prov. Neuquen

Mes	Dias	Tm	Tdc-Tm	Tm-Tdr	HR	Radiación solar media mensual								
						Norte	Noreste	Este	Sureste	Sur	Suroeste	Oeste	Noroeste	Horizontal
()	()	(ºC)	(ºC)	(ºC)	(%)	(W/m²)								
Enero	31	23,9	0	3,9	36	128	179	196	147	88	148	194	174	343
Febrero	28	23,5	0	3,5	41	157	182	176	119	68	124	183	187	300
Marzo	31	20,3	0	0,3	50	182	174	139	80	49	83	144	177	227
Abril	30	16,2	3,8	0	59	205	173	112	51	37	52	109	168	170
Mayo	31	10,1	9,9	0	64	187	141	75	32	29	33	79	147	112
Junio	30	7,9	12,1	0	67	134	98	48	21	20	22	54	106	73
Julio	31	8,5	11,5	0	69	165	126	64	26	24	27	65	126	93
Agosto	31	8,8	11,2	0	56	184	141	82	37	30	40	92	153	129
Septiembre	30	12,4	7,6	0	49	210	185	133	69	45	71	137	189	211
Octubre	31	16,4	3,6	0	46	175	179	155	97	57	107	172	193	267
Noviembre	30	22,1	0	2,1	40	149	189	198	143	82	149	209	199	353
Diciembre	31	23,5	0	3,5	36	127	178	202	156	101	176	226	192	380
Anual	365	16,1	59,7	13,3	51	2003	1945	1580	978	630	1032	1664	2011	2658

Source: own

DEVELOPMENT

The results of each audited case are shown and then discussed and contrasted in temporal order. Starting with the "Eva Perón", then the "Mariano Moreno" and ending with the "Eluney".

"Eva Perón" Municipal Nursery School:

Its construction dates back to the 50's. It is implanted in the middle of a block in a mixed residential/commercial environment. The access front faces southeast and has classrooms facing south, north, west and east. The free-standing building is in the center of a landscaped lot. It consists of 4 small offices, 5 classrooms, kitchen, octagonal SUM and refectory plus 4 sanitary nuclei and annexes. It has a living area of 522.68 m2 and an air-conditioned volume of 1374.65 m3 with an average height of 2.63m. Except for the SUM, which has an average height of 4 m. It is materialized with walls of common bricks plastered on both sides (R= 0.53 m2K/W and K= 1.88 W/m2K), the roof is made of corrugated metal sheet on plank and exposed braces in SUM (R= 0.80 m2K/W and K= 1.26 W/m2K) and the classrooms with suspended plaster ceilings. The window and door joinery is made of large wood (R= 0.17 m2K/W and K= 5.86 W/m2K). The floors are made of calcareous tiles (R= 0.72 m2K/W and K= 1.38 W/m2K). There are classroom ceilings that were rehabilitated, but worsening their thermal insulation by using 3 mm of expanded polyethylene painted aluminum.

From the diagnosis it emerges that the building has an overall volumetric coefficient of thermal losses Gcal (IRAM 11604) of 1.86 W/m3K and a coefficient of unit losses 3.04 W/m2K that results in an annual demand for electrical energy in heating of 37289.48 kWh/year and **71.34 kWh/m2year**, for a base heating temperature of 20°C. In order to define rehabilitation strategies, the losses are analyzed and it is found that it is feasible to intervene the roofs (3.8%), walls (31.9%) and glazes (16.2%, windows and doors), according to Fig. 1, in order to achieve improvements in energy demand, see Fig. 2.

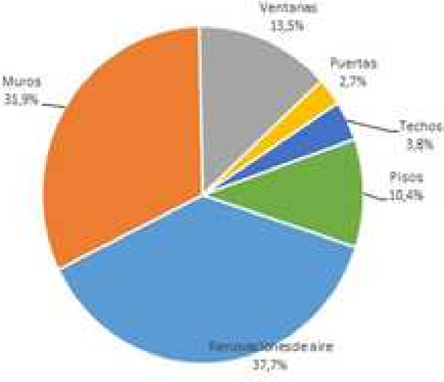


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Fig. 1: Discriminated Heat Losses Original Situation.

Source: own.

Fig. 2: Heating energy demand in kWh/month calculated for TBcal = 20°C, original situation.

The following improvements are proposed to reduce energy demand in winter: a. Insulation in walls with EIFS/ETIS of 50mm. (Km1 = 0.63 W/m2K); b. On ceilings, add 10cm of glass wool with aluminum foil over the ceiling or under sheet metal and replace. (Kt2= 0.36 W/m2K); c. The most expensive intervention is in glazing, i.e. in insulation. An expensive variant is to change all openings or at least movable leaves that allow DVH to be used and something less expensive, to add a new glass glued with sealant and an aluminum S-profile. In fixed glazing, replace them with DVH. Similar situation in the large glazing of the entrances to the building, changing the tempered glass with frames that support DVH. (Kv1 = 2.86 W/m2K); d. It is possible to add a floating floor over 25mm of fiberglass panel. (Kp= 0.52 W/m$^{2K)}$ and e. Replace the heating with balanced shafts for underfloor heating with hot water and natural gas condensing boilers with solar collectors.

Source: own.

Fig. 3: "Eva Perón" garden, comparison between original and improved version.

The implementation of the improvements in walls, ceilings and glazing will reduce the demand for energy in heating by 45.30%. The building will have an overall volumetric coefficient of thermal losses Gcal (IRAM 11604) of 1.31 W/m3K, resulting in an annual heating electricity demand of 20399.15 kWh/year and 39.03 kWh/m2year, for a base heating temperature of 20°C. The building has air conditioning in all rooms and implies that the demand for electrical energy in its cooling has been analyzed. The discrimination of thermal inputs in the building. Sunlight stands out with 57.4%, roofs with 0.6%, walls with 7.0%, and windows with 4.1%. In the winter condition improvements were proposed in these, but sun protection is important. From the diagnosis it emerges that the building has an annual electrical energy demand in refrigeration of 37039.53 kWh/year and 70.86 kWh/m2year, for a base cooling temperature of 20°C. The improvements proposed for the winter are maintained only by adding sun protection in the openings that require it, see Fig. 4. The aim is for glazes to have an FES = 0.13 in windows.

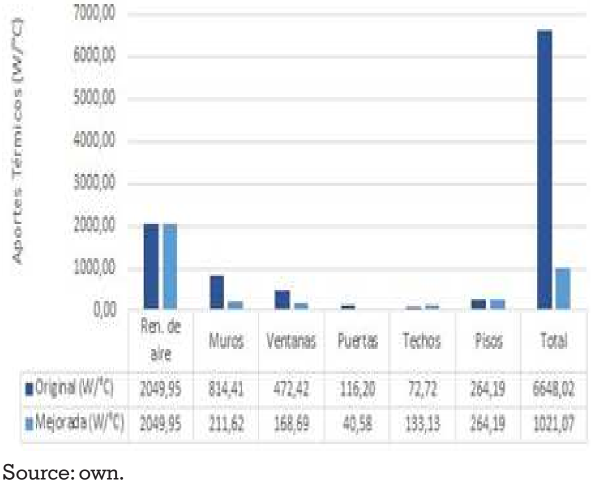

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Fig. 4: "Eva Perón" Garden, comparison of original and improved building. Summer situation.

Figure 5 shows that the total annual reduction of energy in air conditioning with the proposed improvement measures could be 50.90% to keep the building at a constant temperature of 20°C for 8 hours from Monday to Friday all year round. Reducing from 142.21 kWh/m2 year to 69.83 kWh/m2year.

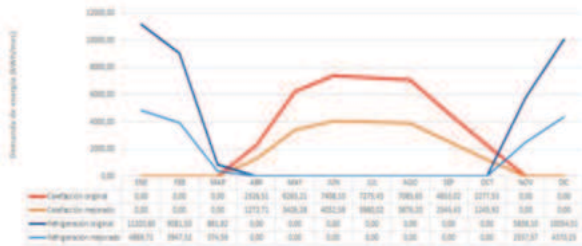

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Fig. 5: Annual comparison of the case: "Eva Perón" nursery school, Neuquén. Neuquén.

This shows the need to implement in-depth solutions, especially in sun protection of glazed surfaces and roofs. Then it remains to plan a thermo-mechanical system of sustainable air conditioning suitable for the building due to its urban implementation.

"Mariano Moreno" Municipal Nursery School:

Its construction dates back to the 70's. It is implanted on a large one-block plot in a mixed residential/commercial environment. The access front faces west and has classrooms facing north, west and east. The building is partially free-standing on a landscaped lot. It consists of 1 small office, 5 classrooms, kitchen, central SUM and refectory plus 5 sanitary centers and annexes. It has a living area of 372.4 m2 and an air-conditioned volume of 1034.27 m3 with an average height of 2.78m. It is materialized with walls of 0.30m of common bricks plastered on both sides (R= 0.53 m2K/W and K= 1.88 W/m2K), the roof is made of H°A° slab (R= 0.34 m2K/W and K= 2.92 W/m2K) with plaster ceiling. The window and door joinery is made of folded sheet metal (R= 0.17 m2K/W and K= 5.86 W/m2K). The floors are made of calcareous tiles (R= 0.72 m2K/W and K= 1.38 W/m2K). The state of conservation is very good.

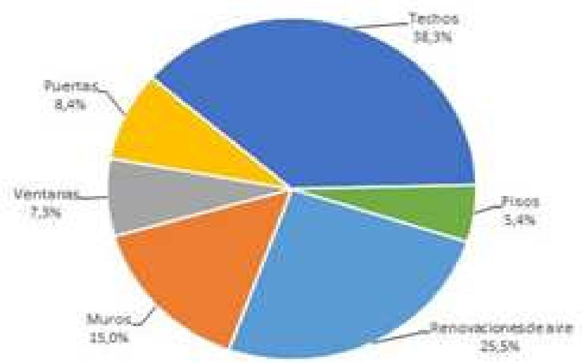

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Fig. 6: Discriminated thermal losses in the original situation.

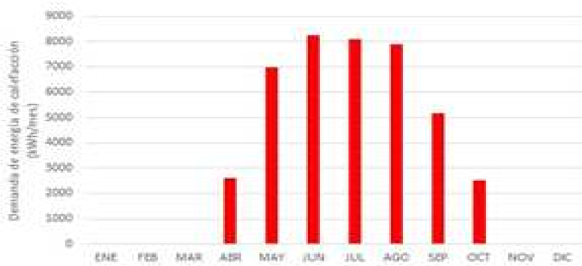

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Fig. 7: Heating energy demand in kWh/month calculated for TBcal = 20°C, original situation.

From the diagnosis it emerges that the building has an overall volumetric coefficient of thermal losses Gcal (IRAM 11604) of 2.74 W/m3K and a coefficient of unit losses 5.67 W/m2K which results in an annual demand for electrical energy in heating of 41435.69 kWh/year and 111.37 kWh/m2year, for a base heating temperature of 20°C. In order to define rehabilitation strategies, the losses were analyzed and it was found that it was feasible to intervene the roofs (38.3%), walls (15.0%) and glazes (15.7%, windows and doors), according to Fig. 6, in order to achieve improvements in energy demand, see Fig. 7. The following improvements are proposed to reduce energy demand in winter: a. EIFS/SATE (*External Insulation Finish System*) type wall insulation with 5 cm of EPS of 30kg/m3 and base coat reinforced with 10x10mm Fiberglass mesh of 110g/^{m2} in the walls with plastered exterior finish. (Km1= 0.50 W/m2K); b. On H°A° slab ceilings, implement an "inverted roof" with "Mastroplac TI" type slabs and finished with expanded clay of 50/70 mm thickness. (Kt$_{2= 0.30 W/m2K)}$; c. The most expensive intervention is in glazing, i.e. in insulation. An expensive variant is to change all openings or at least movable leaves that allow DVH to be used and something less expensive, to add a new glass glued with sealant and an aluminum S-profile. In fixed glazing, replace them with DVH. Similar situation in the large glazing of the entrances to the building, changing the tempered glass with frames that support DVH. (Kv1= 2.86 W/m2K); d. It is possible to add a floating floor on 25mm of fiberglass panel, covered with a 40mm concrete layer (Kp= 0.52 W/m$^{2K)}$ and e. Replace the heating with balanced draughts for underfloor heating with hot water and natural gas condensing boilers with solar collectors.

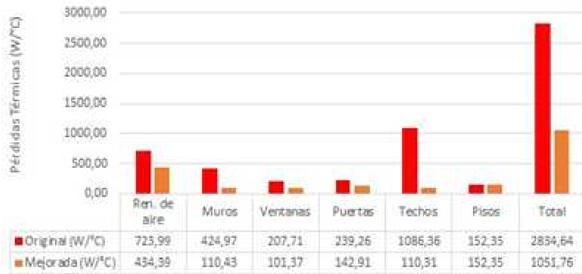

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Fig. 8: "Mariano Moreno" garden, comparison between original and improved version. Winter.

The building has air conditioning in all rooms and implies that the demand for electrical energy in its cooling has been analyzed. Fig. 8 shows the discrimination of thermal inputs in the building. Sunlight stands out with 67.7%, roofs with 6.4%, walls with 3.4%, and windows with 1.7%. In the winter condition improvements were proposed in these, but sun protection is important. From the diagnosis it emerges that the building has an annual electrical energy demand in refrigeration of 39894.63 kWh/year and 107.23 kWh/m2year, for a base cooling temperature of 20°C. After simulating the proposed improvements for heating, solar protection is added in glazes with a FES= 0.13, leaving from the diagnosis that the building has an annual demand for electrical energy in refrigeration, see Fig 9, of 21673.57 kWh/year and 58.26 kWh/m^{2year}, for a base cooling temperature of 20°C.

Source: own.

Figure 9: "Mariano Moreno" Garden, comparison of original and improved building. Summer.

By way of conclusion, figure 10 shows that the total annual reduction of energy in air conditioning with the proposed improvement measures could be 54.45% to keep the building at a constant temperature of 20°C for 8 hours from Monday to Friday throughout the year. Reducing from 218.61 kWh/m2 year to 99.58 kWh/m2year.

Source: own.

Fig. 10: Comparison of annual air conditioning in the case: "Mariano Moreno" Garden, Neuquén.

Municipal Kindergarten "Eluney":

Its construction dates back to the 80's. It is implanted in the middle of a rectangular block in a residential environment. The access front faces west and has classrooms facing south, north and east. The building is freestanding and elevated from Belgrano Street. It consists of a small office, 5 classrooms, kitchen and refectory plus 4 sanitary cores around a covered central courtyard. It is lit by tall windows to the north. It has a living area of 506.45 m2 and an air-conditioned volume of 1761.15 m3 with an average height of 3.41m. Except for the inner courtyard which has an average height of 6 m. It is materialized with hollow brick walls plastered on both sides (R= 0.45 m2K/W and K= 2.21 W/m2K), the roof is made of corrugated metal sheet on planking and exposed braces (R= 0.39 m2K/W and K= 2.58 W/m2K). The window and door joinery is made of bent sheet metal with vertical metal sunshades (R= 0.17 m2K/W and K= 5.86 W/m2K). The floors are made of calcareous tiles (R= 0.72 m2K/W and K= 1.38 W/m2K). It has good natural lighting and the interior lighting system is LED and fluorescent, low consumption. The air conditioning system is by means of TB type natural gas heaters and 3400W AC equipment

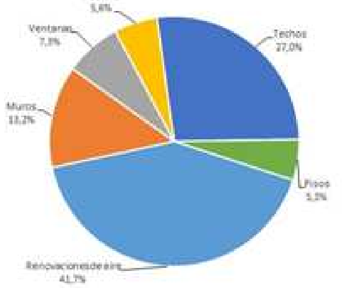

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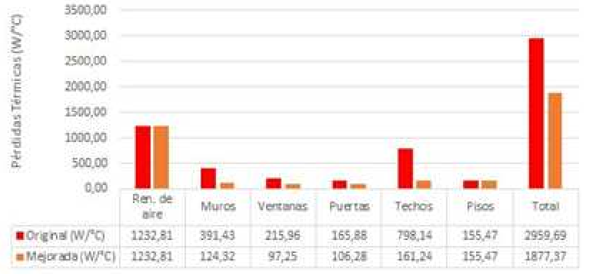
Fig. 11: Thermal losses discriminated in the original situation.

Source: own.

Fig. 12: Heating energy demand in kWh/month calculated for TBcal = 20°C, original situation.

From the diagnosis it emerges that the building has an overall volumetric coefficient of thermal losses Gcal (IRAM 11604) of 1.68 W/m3K and a coefficient of unit losses 3.41 W/m2K that results in an annual demand for electrical energy in heating of 43263.53 kWh/year and 85.44 kWh/m2year, for a base heating temperature of 20°C. In order to define rehabilitation strategies, the losses were analyzed and it was found that it is feasible to intervene the roofs (27.0%), walls (13.2%) and glazes (7.3%, windows), according to fig. 11, in order to achieve improvements in energy demand, see fig. 12.



Source: own.

Fig. 13: "Eluney" nursery school. Comparison of original and improved version. Winter.

The following improvements are proposed to reduce energy demand in winter: a. Insulation in walls with EIFS/ETIS of 50mm. (Km1 = 0.63 W/m2K); b. On ceilings, add 10cm of glass wool with aluminum foil over the ceiling between rafters and replace. (Kt2= 0.36 W/m2K); c. The most expensive intervention is in glazing, i.e. in insulation. An expensive variant is to change all openings or at least movable leaves that allow DVH to be used and something less expensive, to add a new glass glued with sealant and an aluminum S-profile. In fixed glazing, replace them with DVH. Similar situation in the large glazing of the entrances to the building, changing the tempered glass with frames that support DVH. (Kv1= 2.86 W/m2K); d. It is possible to add a floating floor over 25mm of fiberglass panel. (Kp= 0.52 W/m$^{2K)}$ and e. Replace the heating with balanced draughts for underfloor heating with hot water and natural gas condensing boilers with solar collectors.

The implementation of the improvements in walls, ceilings and glazing will reduce the demand for heating energy by 36.51%. The building will have an overall volumetric coefficient of thermal losses Gcal (IRAM 11604) of 1.06 W/m3K, resulting in an annual heating electricity demand of 27442.58 kWh/year and 54.20 kWh/m2year, for a base heating temperature of 20°C, fig. 13.

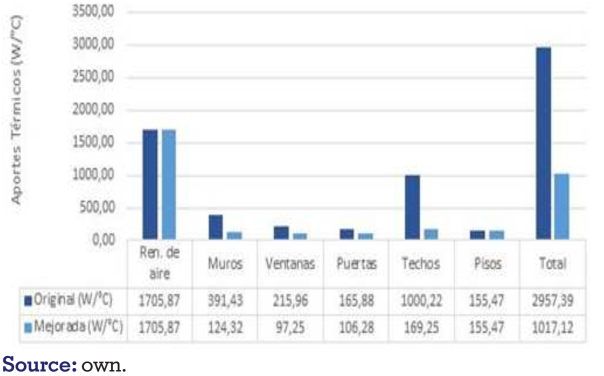


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Fig.14: "Eluney" nursery school. Comparison of original and improved building. Summer.

Thus, the improved proposal implies a 40.92% reduction in the demand for electrical energy in refrigeration, without considering the energy efficiency of air conditioning equipment. Fig. 14 compares the original building with the one resulting from the proposed improvements. Of particular note are the reductions in walls, windows, roofs and sunlight. The diagnosis shows that the building has an annual electrical energy demand for refrigeration of 14892.15 kWh/year and 29.41 kWh/m2year, for a base cooling temperature of 20°C. Fig 15 shows that the total annual reduction of energy in air conditioning with the proposed improvement measures could be 38.17% to keep the building at a constant temperature of 20°C for 8 hours from Monday to Friday all year round. Reducing from 135.22 kWh/m^2 years to 83.61 kWh/m2 years.

Source: own.

Fig. 15: Comparison of annual air conditioning in the case: Eluney nursery school, Neuquén.

CONCLUSIONS

The work shows the great energy inefficiency of buildings that can only function by air-conditioning them thanks to large energy subsidies, mostly in the Patagonian region. Its traditional construction with heavy systems without additional thermal insulation generates significant energy demands ranging from 135.92 to 218.61 kWh/m2 year (TBC 20ºC) but could be significantly reduced between 69.83 and 99.58 kWh/m2year by implementing passive energy rehabilitation measures. That doesn't involve much more than thermally insulating the envelope and protecting the glazed surfaces from the sun. As mentioned, demand could be reduced much further by using sustainable air conditioning systems powered by renewables and reach 15 kWh/m2 year and convert them into low-energy buildings. Perhaps we just need to redefine environmental policies related to building and climate change mitigation and adaptation.

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