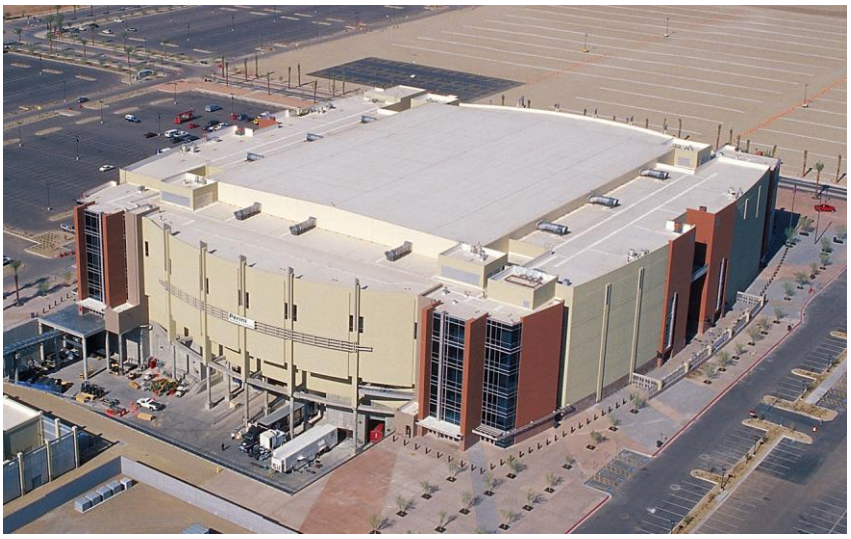
ENVIRONMENTAL PRODUCT DECLARATION

TPO MEMBRANE

SINGLE-PLY ROOFING MEMBRANE
INSTALLATION: MECHANICALLY FASTENED



Single-ply TPO membrane mechanically fastened and representative of 45-, 60- and 80-mil thicknesses

The 1906 Brand
The original Mule-Hide trade name was registered in 1906. Throughout the years, the name associated with industry-leading residential shingles transitioned into a resource devoted to commercial products specializing in single-ply installations.

Mule-Hide keeps the tradition alive by offering low-slope roofing solutions for every type of building.

MHP offers roofing solutions ideal for long-term watertight integrity. All MHP products are manufactured under strict quality control and are available through the largest nationwide distribution channel.

CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

PROGRAM OPERATOR	UL Environment
DECLARATION HOLDER	Carlisle SynTec Systems
DECLARATION NUMBER	4787408569.102.1
DECLARED PRODUCT	TPO Single Ply Roofing Membrane (Mechanically Fastened)
REFERENCE PCR	PCR for Single Ply Roofing Membranes. ASTM International.
DATE OF ISSUE	September 26, 2018
EXPIRATION DATE	September 29, 2021
CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications

The PCR review was conducted by:	PCR Review Panel
	Peer review report available upon request
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This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☒ EXTERNAL	Grant R. Martin
	Grant R. Martin, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Thomas P. Gloria
	Thomas P. Gloria, Industrial Ecology Consultants

This EPD conforms with ISO 21930:2007 & EN 15804

Product Definition

Description of Product

The product system evaluated in this report is an installed single ply thermoplastic polyolefin (TPO) roofing membrane at the finished nominal thicknesses produced by Mule-Hide and listed in Table 1.

Table 1: Membrane specification and standard

Roof System	Roof System Component	Declared Thicknesses and Weights	Standard
Thermoplastic polyolefin (TPO)	Membrane	45 mils: 1.12 kg/m^2 60 mils: 1.42 kg/m^2 80 mils: 1.95 kg/m^2	ASTM D6878

Application and Uses

Mule-Hide's TPO reinforced membrane is a premium, heat-weldable, single-ply thermoplastic polyolefin (TPO) sheet designed for new and retrofit low-slope roofing applications. TPO membranes can be mechanically fastened or fully adhered as part of a complete roofing assembly. Mule-Hide TPO membranes use advanced polymerization technology that combines the flexibility of ethylenepropylene (EP) rubber with the heat weldability of polypropylene. All Mule-Hide TPO membranes include a state-of-the-art weathering package. This technology enables Mule-Hide TPO to withstand the extreme weatherability testing intended to simulate exposure to severe climates. Physical properties of the membrane are enhanced by a strong polyester fabric that is encapsulated between the TPO-based top and bottom plies. The combination of the fabric and TPO plies provides high breaking and tearing strength, as well as excellent puncture resistance. The relatively smooth surface of the membrane produces a total surface fusion weld that results in consistent, watertight, monolithic roof assembly.

Mule-Hide TPO membranes are available in highly reflective white, tan and gray, in 45-mil and 60-mil, and 80-mil thicknesses. Mule-Hide's TPO is offered in 4- and 6-ft perimeter sheets and 8-, 10- and 12-ft field sheets.

Health Safety & Environmental Aspects During Installation

Exercise caution when walking on a wet membrane. Membranes are slippery when wet.

For white membranes the following precautions apply:

- Sunglasses that filter out ultraviolet light are strongly recommended as the white surface intensifies sunlight through reflection.
- White surfaces reflect heat and may become slippery due to frost and ice build-up. Exercise extreme caution during cold conditions to prevent falls.
- Use caution when working close to a roof edge when surrounding area is snow covered as roof edge may not be clearly visible.

Product Life Cycle Description

Material Content

Table 2 shows the input material for TPO roofing membranes and their material percentages for the three membrane thicknesses.

Table 2: Average composition of TPO roofing membrane

Material	[%]
Base resin [polypropylene (PP)/ ethylene propylene diene monomer (EPDM)]	71
Fire retardants	14
Polyester scrim	7
Weathering agents	6
Pigments	1

Manufacturing Process

The main material input into the TPO manufacturing process is polyolefin polymer in the form of pellets. Other ingredients essential to the TPO membrane performance, such as fire retardants and anti-oxidant, are also added. Optional ingredients, such as colorants and slip agents, can be added to increase the aesthetic appeal and improve the processability, respectively. The mixture is blended together, heated, and extruded onto the top and bottom of polyester reinforcing scrim to form laminated layers. The process is run to have the reinforcing scrim sandwiched in the middle of the top and bottom ply, each with a precisely controlled thickness. The TPO membrane is cooled by passing it through a series of rollers with temperatures controlled by closed loop chillers. The membrane is then cut to the desired length, wound onto a cardboard core, and wrapped in plastic film. Membrane rolls are packaged and labelled before they are shipped to construction sites for installation.

Figure 1 shows the manufacturing process for TPO membrane.

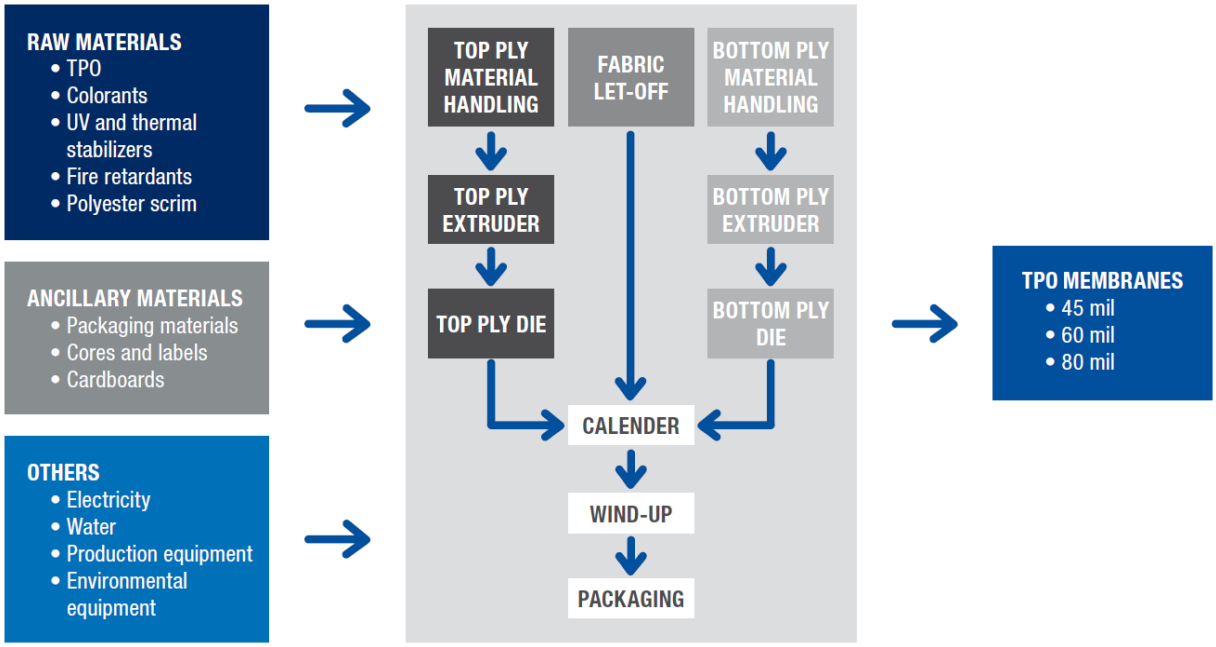

Figure 1: TPO production process map

Installation

The installation process was modeled following common practice in which TPO membrane is mechanically fastened.

Table 3 shows the material inputs, material outputs, and emissions associated with the installation of 1 m^2 of TPO membrane. This scenario is identical to the one used for the industry-average reinforced EPDM membrane EPD produced by SPRI, with only the weight of the membrane adjusted according to membrane thickness. It is assumed to be representative for all thicknesses. Packaging materials are disposed of after the membrane is installed at the building site.

Table 3: Installation of TPO membrane, unit process (per declared unit)

I/O	Material	Value	Unit
Inputs	TPO roofing membrane (packaged), incl. 2.5% overlap	1.025	m^2
	Steel fasteners	0.0242	kg
	Electricity for power tools	0.00360	MJ
Outputs	1 m^2 of installed TPO roofing membrane	1	m^2
	Packaging waste (from membrane)	*	kg

* varies with membrane thickness

End-of-Life

At the end of the roofing membrane's useful life, it was assumed that the membrane material, as well as any fasteners or adhesive substances, are manually removed from the building and then landfilled. This aligns with the disposal method used in the industry average EPD produced by SPRI. Transport to landfill was approximated with 20 miles via large dump truck.

Life Cycle Assessment – Product Systems and Modeling

Declared Unit

The declared unit evaluated is 1 m^2 of single ply roofing membrane for a stated product thickness. As the use stage is excluded from this study, no reference service life is defined.

Life Cycle Stages Assessed

The life cycle assessment (LCA) conducted includes the production, transport to installation site, installation, and end-of-life (EoL) stages.

System Boundaries

System boundaries are summarized in Figure 2 for the analysis scope of "cradle-to-building with EoL stage" (i.e., production with installation and EoL stages). Excluded modules are indicated by "MND" or "module not declared". As is typical of works of life cycle assessment, the construction and maintenance of capital equipment, such as production equipment in the manufacturing stage, are not included in the system, nor are human labor and employee commute. The use stage is also outside the scope of this study.

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END-OF-LIFE STAGE			
Raw material supply	Transport	Manufacturing	Transport	Construction-installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
X	X	X	X	X	MND	MND	MND	MND	MND	MND	MND	X	X	X	X

Figure 2: Life cycle stages included in system boundary

Assumptions

In cases where no matching life cycle inventories were available to represent a flow, proxy data were applied based on conservative assumptions regarding environmental impacts.

Transportation

Transportation distances and the associated modes of transport are included for the transport of the raw materials, operating materials, and auxiliary materials to production facilities.

Period under Consideration

All primary data were collected for the year 2014. All secondary data come from the GaBi Professional databases and are representative of the years 2010-2013.

Manufacturing Locations

Mule-Hide manufactures its membranes in the United States. Specifically, TPO membranes are manufactured in Senatobia, MS and Tooele, UT. As such, the geographical coverage for this study is based on US system boundaries for all processes and products. Whenever US background data were not readily available, European data or global data were used as proxies.

Background Data

The LCA model was created using the GaBi ts software system for life cycle engineering, developed by thinkstep AG. The GaBi Professional LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

Cut- Off Criteria

Per the PCR, the cut-off criteria for flows to be considered within each system boundary are as follows:

- Mass: If a flow is less than 1% of the cumulative mass of the model flows, it may be excluded, provided its environmental relevance is minor, based on a sensitivity analysis.
- Energy: If a flow is less than 1% of the cumulative energy of the system model, it may be excluded, provided its environmental relevance is minor, based on a sensitivity analysis.
- Environmental relevance: If a flow meets the above two criteria, but is determined to contribute 2% or more to the selected impact categories of the products underlying the EPD, based on a sensitivity analysis, it is included within the system boundary.

At least 95% of the mass flows shall be included and the life-cycle impact data shall contain at least 95% of all elementary flows that contribute to each of the declared category indicators. A list of hazardous and toxic materials and substances shall be included in the inventory and the cut-off rules do not apply to such substances.

No cut-off criteria were applied for this study. All available energy and material flow data were included in the model.

Data Quality Requirements

As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. Seasonal variations were balanced out by using yearly averages. All background data are sourced from GaBi databases with the documented precision. Each foreground process was checked for mass balance and completeness of the emission inventory. No data were knowingly omitted. Completeness of foreground unit process data is considered to be high. All background data are sourced from GaBi databases with the documented completeness.

Allocation

As several products are often manufactured at the same plant, Mule-Hide used mass allocation to report data. Mass allocation was selected since the environmental burden in the industrial process (energy consumption, emissions, etc.) is primarily governed by the mass throughput of each sub-process.

Life Cycle Assessment – Results and Analysis

Use of Material Resources

The material resource consumption associated with the TPO roofing membranes is presented below in Table 4 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages. The fresh water indicator accounts for net water consumption.

Table 4: Use of material resources for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
Non-renewable materials [kg]					
TPO 45 mils	4.01	0.00162	0.0879	0.280	**4.38**
TPO 60 mils	5.11	0.00206	0.0957	0.351	**5.56**
TPO 80 mils	7.33	0.00298	0.111	0.482	**7.93**
Renewable materials [kg]					
TPO 45 mils	1,770	1.18	24.9	24.0	**1,820**
TPO 60 mils	2,140	1.50	24.9	30.1	**2,200**
TPO 80 mils	2,540	2.17	24.5	41.3	**2,610**
Fresh water [L]					
TPO 45 mils	166	0.0697	-0.0352*	-0.766*	**165**
TPO 60 mils	211	0.0889	-0.0688*	-0.962*	**210**
TPO 80 mils	297	0.128	-0.141*	-1.32*	**296**

* Water consumption values are negative due to waste sent to landfill during construction and at EoL. A landfill introduces blue water to the watershed because it collects rainwater during its lifetime that is eventually released as ground water, therefore more water is coming out of the process than going in. Rainwater is not blue water and is therefore not included in the water consumption metric.

Primary Energy by Life Cycle Stage

The primary energy demand associated with the TPO roofing membranes is presented below in Table 5 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages.

Table 5: Primary energy consumption results for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
Non-renewable fossil [MJ, LHV]					
TPO 45 mils	88.8	0.348	0.234	0.852	**90.2**
TPO 60 mils	113	0.444	0.244	1.07	**115**
TPO 80 mils	160	0.640	0.258	1.47	**162**
Non-renewable nuclear [MJ, LHV]					
TPO 45 mils	3.60	0.00185	0.0279	0.0237	**3.65**
TPO 60 mils	4.66	0.00236	0.0249	0.0298	**4.72**
TPO 80 mils	6.99	0.00341	0.0176	0.0409	**7.05**
Renewable (solar, wind, hydroelectric, geothermal) [MJ, LHV]					
TPO 45 mils	4.42	0.00548	-0.00440*	0.0460	**4.47**
TPO 60 mils	5.47	0.00700	-0.0226*	0.0578	**5.51**
TPO 80 mils	7.05	0.0101	-0.0771*	0.0794	**7.07**
Renewable (biomass) [MJ, LHV]					
TPO 45 mils	6.31×10^{-11}	4.52×10^{-15}	2.13×10^{-12}	9.99×10^{-13}	6.62×10^{-11}
TPO 60 mils	7.97×10^{-11}	5.77×10^{-15}	2.14×10^{-12}	1.25×10^{-12}	8.31×10^{-11}
TPO 80 mils	1.11×10^{-10}	8.32×10^{-15}	2.15×10^{-12}	1.72×10^{-12}	1.15×10^{-10}

* Net negative renewable energy values have occurred due to the material credit associated with recovering a fraction of wooden pallets and should not be interpreted in a way that an increase in consumption of the products under study will lead to any 'reversal' of environmental burden elsewhere.

Life Cycle Impact Assessment

The environmental impacts associated with the TPO roofing membrane are presented below in Table 6 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages.

Table 6: Life cycle impact category results for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
GWP [kg CO_2-eq]					
TPO 45 mils	3.48	0.0252	0.0900	0.0551	**3.65**
TPO 60 mils	4.42	0.0321	0.113	0.0692	**4.64**
TPO 80 mils	6.27	0.0463	0.166	0.0951	**6.58**

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
AP [kg SO_2-eq]					
TPO 45 mils	0.00818	1.20×10^{-4}	3.12×10^{-4}	8.27×10^{-4}	**0.00944**
TPO 60 mils	0.0105	1.54×10^{-4}	3.93×10^{-4}	0.00104	**0.0120**
TPO 80 mils	0.0151	2.22×10^{-4}	5.71×10^{-4}	0.00144	**0.0173**
EP [kg N-eq]					
TPO 45 mils	8.12×10^{-4}	1.09×10^{-5}	6.79×10^{-5}	3.07×10^{-4}	**0.00120**
TPO 60 mils	0.00103	1.40×10^{-5}	8.68×10^{-5}	3.88×10^{-4}	**0.00152**
TPO 80 mils	0.00147	2.01×10^{-5}	1.28×10^{-4}	5.35×10^{-4}	**0.00214**
ODP [kg CFC 11-eq]					
TPO 45 mils	3.51×10^{-10}	2.12×10^{-13}	6.11×10^{-14}	1.30×10^{-12}	**3.53×10^{-10}**
TPO 60 mils	4.57×10^{-10}	2.71×10^{-13}	$-3.27 \times 10^{-13*}$	1.63×10^{-12}	**4.59×10^{-10}**
TPO 80 mils	6.94×10^{-10}	3.90×10^{-13}	$-1.23 \times 10^{-12*}$	2.24×10^{-12}	**6.96×10^{-10}**
SFP [kg O_3-eq]					
TPO 45 mils	0.139	0.00380	0.00178	0.00734	**0.152**
TPO 60 mils	0.177	0.00485	0.00214	0.00923	**0.193**
TPO 80 mils	0.250	0.00700	0.00290	0.0127	**0.272**

*ODP values are negative during installation due to the credit given for energy recovered from the landfill of packaging waste and should not be interpreted in a way that an increase in consumption of the products under study will lead to any 'reversal' of environmental burden elsewhere.

Waste Generation

The waste generation associated with the TPO roofing membrane is presented below in Table 7 for the production (A1-A3), transport to installation site (A4), installation (A5), and EoL (C1-C4) stages.

Table 7: Waste generation results for TPO membrane, per declared unit

Indicator	Production A1-A3	Transport to Site A4	Installation A5	EoL C1-C4	Total
Waste generated [kg]					
TPO 45 mils	0.199	1.13×10^{-5}	0.125	1.16	**1.48**
TPO 60 mils	0.246	1.49×10^{-5}	0.164	1.49	**1.90**
TPO 80 mils	0.373	1.95×10^{-5}	0.210	2.01	**2.60**

Additional Environmental Information

Product Performance

UV Resistance – TPO has excellent UV resistance as evidenced in the ASTM G155 Accelerated Xenon Arc Weathering test. TPO white reinforced membrane has UV resistance that has tested in excess of 20,000 kJ/m^2 which is more than double the ASTM requirements.

Resistance to unwanted biological growth – Mule-Hide TPO roofing membrane has been tested in accordance with ASTM1 G21 (Practice for determining resistance of synthetic polymeric materials to fungi) by an independent laboratory. Fungi includes mold and mildew. The results indicate that Mule-Hide TPO is resistant to fungal growth. Mule-Hide TPO does not contain any ingredients that are metabolized by microbials and some ingredients act to inhibit the growth of fungi, bacteria and algae. Mule-Hide TPO is not susceptable to degradation from microbials.

Resistance to hail damage – Mule-Hide TPO has UL 2218 Class 4 hail resistance rating.This test is designed to test the roof systems resistance to damage from the most severe hail strikes.

Roof Surface Solar Reflectance

Mule-Hide TPO membranes have radiative properties that qualify the material for the Department of Energy's - ENERGY STAR rating, Cool Roof Rating Council (CRRC), and LEED requirements. White and tan membranes are also ENERGY STAR certified and California Title 24 compliant.

Mule-Hide white TPO has a initial solor reflectance of 0.79 and initial emissivity of 0.90. Both of these values are critical when evaluating solar reflectance index (SRI) values which represent the potential energy savings impact of reflective roofing, such as TPO. Materials with the highest SRI values are the coolest choices for roofing. Reflective roofing membranes are generally recommended in climates where energy usage for cooling exceeds that of heating.

Mule-Hide TPO comes with an optional CLEAN protective film on the surface of the TPO to protect the reflectivity of the membrane during installation.

Recycling

All post-industrial scrap is recycled back into the product through an in-house process. Additionally, Mule-Hide offers recycling options for TPO membrane after use, through a partnership with Nationwide Foam.

To reduce waste during the construction of the roofing system, Mule-Hide also offers pre-fabricated flashings and accessories for details and penetrations.

Environmental Stewardship

Mule-Hide TPO membranes conform to requirements of the US E.P.A. Toxic Leachate Test (40 CFR part 136) performed by an independent analytical laboratory.

Mule-Hide TPO membrane is chlorine-free with no halogenated flame retardants.

References

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- thinkstep. (2014). GaBi LCA Database Documentation. Retrieved from thinkstep AG: http://database-documentation.gabi-software.com

LCA Development

The EPD and background LCA were prepared by thinkstep, Inc.

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