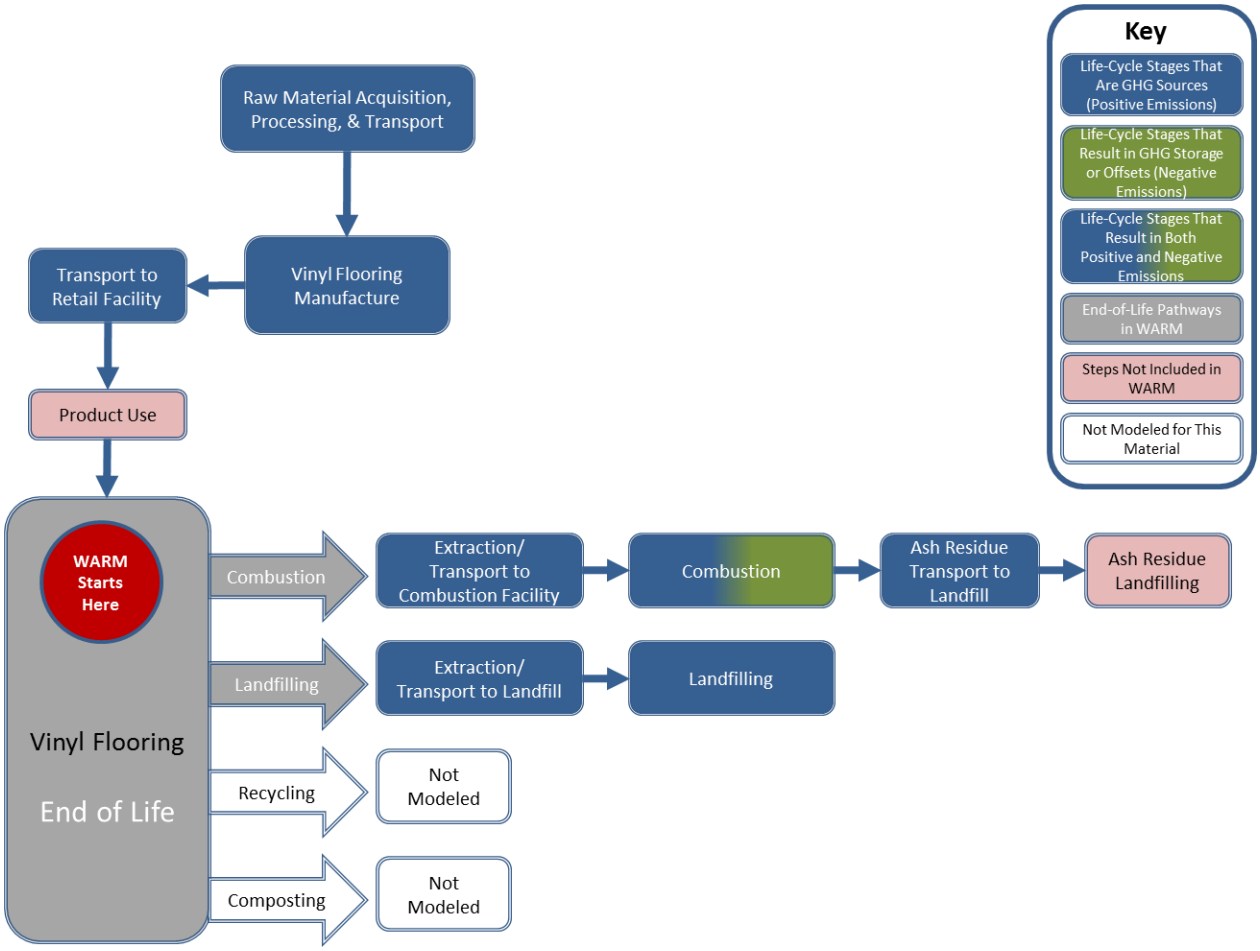
VINYL FLOORING

1. INTRODUCTION TO WARM AND VINYL FLOORING

This chapter describes the methodology used in EPA's Waste Reduction Model (WARM) to estimate streamlined life-cycle greenhouse gas (GHG) emission factors for vinyl flooring beginning at the waste generation reference point.[1] EPA uses the WARM GHG emission factors to compare the net emissions associated with vinyl flooring in the following three waste management alternatives: source reduction, combustion, and landfilling. Exhibit 1 shows the general outline of materials management pathways for vinyl flooring in WARM. For background information on the general purpose and function of WARM emission factors, see the Introduction & Overview chapter. For more information on Source Reduction, Combustion, and Landfilling, see the chapters devoted to those processes.

Exhibit 1: Life Cycle of Vinyl Flooring in WARM



Two major types of vinyl flooring, (1) sheet flooring and (2) tile, have applications in commercial and residential buildings. Vinyl composition tile (VCT) is the industry standard for most commercial applications because it is durable, resilient, and relatively low cost. Sheet flooring is more commonly used in residential applications, such as kitchens and bathrooms, and generally it contains a higher percentage of vinyl resins, causing it to be more expensive.

[1] EPA would like to thank Mr. Richard Krock of The Vinyl Institute for his efforts at improving these estimates.

All vinyl flooring is composed of polyvinyl chloride (PVC) resin along with additives, such as plasticizers, stabilizers, pigments, and fillers. Vinyl flooring products can be made using different manufacturing processes and material compositions. The density of vinyl flooring will also vary, depending on its intended use (Baitz et al., 2004). Some floors can contain as much as 55 percent vinyl, while others may contain as little as 11 percent (Vinyl In Design, 2009). For all PVC flooring products, the resin is applied over a backing material and a transparent protective wear layer is added on top. During installation, VCT is secured using adhesive tabs, spray, or a self-adhesive backing (Floor Ideas, 2009; Armstrong, 2009).

2. LIFE-CYCLE ASSESSMENT AND EMISSION FACTOR RESULTS

The GHG life-cycle boundaries in WARM start at the point of waste generation, or the moment a material is discarded, as the reference point and considers upstream GHG emissions only when the production of new materials is affected by material management decisions. Recycling and source reduction are the two materials management options that affect the upstream production of materials, and consequently are the only management options that include upstream GHG emissions. For more information on evaluating upstream emissions, see the chapters on Recycling, and Source Reduction.

WARM considers emission factors only for source reduction, combustion, and landfilling for vinyl flooring. As Exhibit 2 illustrates, all of the GHG sources and sinks relevant to vinyl flooring in this analysis are contained in the raw materials acquisition and manufacturing (RMAM) and materials management sections of the life-cycle assessment.

Exhibit 2: Vinyl Flooring GHG Sources and Sinks from Relevant Materials Management Pathways

Materials Management Strategies for Vinyl Flooring	GHG Sources and Sinks Relevant to Vinyl Flooring		
	Raw Materials Acquisition and Manufacturing	**Changes in Forest or Soil Carbon Storage**	**End of Life**
Source Reduction	**Offsets** • Virgin manufacture process energy • Virgin manufacture process non-energy • Transportation of raw materials and products	NA	NA
Recycling	Not modeled in WARM		
Composting	Not applicable because vinyl flooring cannot be composted		
Combustion	NA	NA	**Emissions** • Transport to combustion facility • Combustion emissions **Offsets** • Avoided utility emissions
Landfilling	NA	NA	**Emissions** • Transport to construction and demolition landfill • Landfilling machinery

WARM analyzes all of the GHG sources and sinks outlined in Exhibit 2 and calculates net GHG emissions per short ton of vinyl flooring inputs. For more detailed methodology on emission factors, see Sections 4.2 – 4.5. Exhibit 3 outlines the net GHG emissions for vinyl flooring under each materials management option.

Exhibit 3: Net Emissions for Vinyl Flooring under Each Materials Management Option ($MTCO_2E$/Short Ton)

Material/Product	Net Source Reduction (Reuse) Emissions for Current Mix of Inputs	Net Recycling Emissions	Net Composting Emissions	Net Combustion Emissions	Net Landfilling Emissions
Vinyl Flooring	-0.61	NA	NA	-0.30	0.04

Note: Negative values denote net GHG emission reductions or carbon storage from a material management practice.
NA = Not applicable.
NE = Not estimated because data are insufficient.

3. RAW MATERIALS ACQUISITION AND MANUFACTURING

For vinyl flooring, the GHG emissions associated with RMAM are (1) GHG emissions from energy used during the acquisition and manufacturing processes, (2) GHG emissions from energy used to transport materials, and (3) non-energy GHG emissions resulting from manufacturing processes. Process non-energy GHG emissions occur during the manufacture of certain materials and are not associated with energy consumption.

Vinyl flooring is composed of PVC resin along with additives such as plasticizers, stabilizers, pigments, and fillers. Each material is acquired, transported, and processed individually before being transported to the vinyl flooring processing facility. Vinyl flooring products can be made using different manufacturing processes and material compositions. EPA located publicly available life-cycle inventory (LCI) data for virgin VCT in *Building for Environmental and Economic Sustainability* (BEES®) (Lippiatt, 2007) and general data on PVC flooring in a European Commission report on PVC materials (Baitz et al., 2004). We used VCT data primarily from BEES to develop GHG emission factors for virgin manufacturing of vinyl flooring because of its applicability to the U.S. market and the transparency of the data relative to other sources.

According to BEES, VCT is manufactured from a vinyl polymer, plasticizer, and limestone with an acrylic latex finishing coat applied at tile manufacture (Lippiatt, 2007). Similarly, Baitz et al. (2004) estimates that, on average, vinyl flooring contains PVC resin, filler, plasticizers, pigments, and stabilizers. Today, the standard filler for vinyl is limestone; common stabilizers tend to be made of zinc, calcium, and tin; and the industry uses two plasticizers from the phthalate family, diisononyl phthalate and benzyl butyl phthalate (Helm, 2009). While stabilizers and process aides typically are used in vinyl flooring, they are not included in this analysis because sufficient data are lacking.

The RMAM calculation in WARM also incorporates retail transportation, which includes emissions for the average truck, rail, water, and other modes required to transport vinyl flooring from the manufacturing facility to the retail/distribution point, which may be the customer or various other establishments (e.g., warehouse, distribution center, wholesale outlet). The energy and GHG emissions from retail transportation appear in Exhibit 4. Transportation emissions from the retail point to the consumer are not included. EPA obtained the miles-travelled fuel-specific information from the 2007 U.S. Census Commodity Flow Survey (BTS, 2013) and *Greenhouse Gas Emissions from the Management of Selected Materials* (EPA, 1998).

Exhibit 4: Retail Transportation Energy Use and GHG Emissions

Material/Product	Average Miles per Shipment	Retail Transportation Energy (Million Btu per Short Ton of Product)	Retail Transportation Emissions ($MTCO_2E$ per Short Ton of Product)
Vinyl Flooring	497	0.58	0.04

4. MATERIALS MANAGEMENT METHODOLGIES

This analysis considers source reduction, landfilling, and combustion pathways for materials management of vinyl flooring. For vinyl flooring, source reduction and combustion result in net negative emissions (i.e., a net reduction in GHG emissions), while landfilling results in slightly positive net emissions.

4.1 SOURCE REDUCTION

When a material is source reduced, GHG emissions associated with making the material and managing the postconsumer waste are avoided. As discussed previously, source reduction for vinyl flooring comes from avoided emissions associated with raw material acquisition and the VCT manufacturing process. For more information about source reduction, refer to the chapter on source reduction.

Exhibit 5 outlines the GHG emission factor for source reducing vinyl flooring. EPA calculates the GHG benefits of source reduction as the emissions savings from avoided raw materials acquisition and manufacturing (see Section 3) of vinyl flooring produced from 100-percent virgin inputs. EPA assumes the current mix is 100-percent virgin inputs because very little vinyl flooring is produced from recycled inputs.

Exhibit 5: Source Reduction Emission Factors for Vinyl Flooring ($MTCO_2E$/Short Ton)

Material/ Product	Raw Material Acquisition and Manufacturing for Current Mix of Inputs	Raw Material Acquisition and Manufacturing for 100% Virgin Inputs	Forest Carbon Storage for Current Mix of Inputs	Forest Carbon Storage for 100% Virgin Inputs	Net Emissions for Current Mix of Inputs	Net Emissions for 100% Virgin Inputs
Vinyl Flooring	-0.61	-0.61	NA	NA	-0.61	-0.61

– = Zero emissions.

Note: Negative values denote net GHG emission reductions or carbon storage from a material management practice.

4.1.1 Developing the Emission Factor for Source Reduction of Vinyl Flooring

To calculate the avoided GHG emissions for vinyl flooring, EPA first looked at three components of GHG emissions from RMAM activities: (1) process energy, (2) transportation energy, and (3) non-energy GHG emissions. Exhibit 6 shows the results for each component and the total GHG emission factors for source reduction. More information on each component making up the final emission factor follows.

Exhibit 6: Raw Material Acquisition and Manufacturing Emission Factor for Virgin Production of Vinyl Flooring ($MTCO_2E$/Short Ton)

(a) Material/Product	(b) Process Energy	(c) Transportation Energy	(d) Process Non-Energy	(e) Net Emissions (e = b + c + d)
Vinyl Flooring	0.52	0.08	0.01	0.61

To calculate this factor, EPA first obtained an estimate of the amount of energy required to acquire and produce one short ton of vinyl flooring. EPA obtained data on the extraction and processing of PVC resin from the National Renewable Energy Laboratory's (NREL) U.S. LCI Database, based on LCI data developed by Franklin Associates for the American Chemistry Council (Franklin Associates, 2007). EPA also used data on limestone manufacturing at the mine from the U.S. LCI Database. EPA obtained energy inputs for plasticizer manufacturing from a report prepared for the European Council for Plasticisers and Intermediates (ECPI) (ECOBILAN, 2001).

Finally, EPA gathered manufacturing data for vinyl acetate and styrene-butadiene adhesive from ecoinvent version 2.1 (ecoinvent Centre, 2008). The data for vinyl acetate manufacturing represents the European average at the plant, while data for adhesive manufacturing represents styrene-butadiene dispersion for latex at the plant. Both of these life-cycle datasets include infrastructure (i.e., energy and GHG emissions associated with producing the capital equipment used to make the products), which is not included in WARM's life-cycle boundaries. Because energy and GHG emissions associated with infrastructure are typically small, and the vinyl acetate and adhesive GHG emissions contribute to 1 percent and 10 percent of the total process energy respectively, we concluded that the additional inputs associated with infrastructure are likely small.

EPA took data on the manufacturing of vinyl flooring from the BEES model (Lippiatt, 2007). This source specifically analyzes VCT. Because the processing energy estimates for limestone, PVC, vinyl acetate, and VCT manufacturing do not include the precombustion energy of the fuels, ICF added precombustion values based on precombustion estimates by fuel types in Franklin Associates (2007). Although the plasticizer data do include precombustion energy, these estimates are representative of European processes. For consistency with the other inputs, ICF applied Franklin Associates precombustion energy estimates to the plasticizer. Precombustion energy is already included with the aggregated adhesive manufacturing data supplied by ecoinvent, and EPA was not able to disaggregate this data into precombustion and combustion estimates.

EPA then multiplied the amount of energy required to acquire and produce one short ton of vinyl flooring, broken down by fuel mix, by the fuel-specific carbon content. The sum of the resulting GHG emissions by fuel type comprises the total process energy GHG emissions, including both carbon dioxide (CO_2) and methane (CH_4), from all fuel types used in vinyl flooring production. The process energy used to produce vinyl flooring and the resulting emissions appear in Exhibit 7.

Exhibit 7: Process Energy GHG Emissions Calculations for Virgin Production of Vinyl Flooring

Material/Product	Process Energy per Short Ton Made from Virgin Inputs (Million Btu)	Process Energy GHG Emissions ($MTCO_2E$/Short Ton)
Vinyl Flooring	9.58	0.52

Transportation energy emissions result from fossil fuels used to transport raw materials and intermediate products for vinyl floor production. EPA obtained data on transportation of PVC resin from the NREL U.S. LCI Database, which is based on LCI data developed by Franklin Associates for the American Chemistry Council (Franklin Associates, 2007). The LCI Database assumes limestone manufacturing requires no transportation. Again, EPA took transportation information for vinyl acetate from ecoinvent version 2.1 (ecoinvent Centre, 2008). Energy use associated with the transport of raw materials for plasticizer manufacturing is based on a report prepared for ECPI (ECOBILAN, 2001).

The BEES Model (Lippiatt, 2007) provides data on the transportation of each component to VCT flooring manufacturing, as well as the transportation of adhesives to the end user. EPA obtained data on retail transportation of the VCT flooring to the construction site from the U.S. Census Bureau (BTS, 2013).

The calculations for estimating the transportation energy emission factor for vinyl flooring appear in Exhibit 8.

Exhibit 8: Transportation Energy Emissions Calculations for Virgin Production of Vinyl Flooring

Material/Product	Transportation Energy per Short Ton Made from Virgin Inputs (Million Btu)	Transportation Energy GHG Emissions ($MTCO_2E$/Short Ton)
Vinyl Flooring	0.65	0.05

Note: The transportation energy and emissions in this exhibit do not include retail transportation, which is presented separately in Exhibit 4.

Process non-energy GHG emissions occur during manufacturing, but they are not related to consuming fuel for energy. Petrochemical processes generate process non-energy emissions in the production of PVC for vinyl flooring. To estimate these emissions, we applied non-energy process GHG emission factors for ethylene and ethylene dichloride and vinyl chloride monomer developed by the Intergovernmental Panel on Climate Change (IPCC) (2006, p. 3.74, 3.77). Exhibit 9 shows the components for estimating process non-energy GHG emissions for vinyl flooring.

Exhibit 9: Process Non-Energy Emissions Calculations for Virgin Production of Vinyl Flooring

Material/Product	CO_2 Emissions (MT/Short Ton)	CH_4 Emissions (MT/Short Ton)	CF_4 Emissions (MT/Short Ton)	C_2F_6 Emissions (MT/Short Ton)	N_2O Emissions (MT/Short Ton)	Non-Energy Carbon Emissions ($MTCO_2E$/Short Ton)
Vinyl Flooring	0.00	0.00	–	–	–	0.01

– = Zero emissions.

4.2 RECYCLING

Use of post-consumer recycled PVC is possible, but the number of different VCT manufacturers and an inconsistent supply of post-consumer vinyl material make it difficult to develop a representative estimate. Lippiatt (2007, p. 167) assumes a conservative composition of 1 percent post-consumer recycled PVC. According to Helm (2009), vinyl manufacturers use post-consumer recycled content in the bottom layer of their vinyl products, where less purity is required. Numerous manufacturers, including Mannington, Centiva, and Toli, currently use post-consumer recycled PVC on the back of their products, although the PVC is generally sourced from other PVC products other than discarded vinyl flooring. Because the data available is insufficient, EPA does not include an emission factor in WARM for vinyl flooring recycling.

4.3 COMPOSTING

Vinyl flooring is not subject to aerobic bacterial degradation and cannot be composted; therefore, EPA does not include an emission factor in WARM for composting of vinyl flooring.

4.4 COMBUSTION

Although vinyl flooring is not typically combusted in the United States, combustion is a common end-of-life pathway for vinyl flooring in other countries, specifically in Europe. Franklin Associates (2007) provides energy content of PVC resin. The combustion emission factor for vinyl flooring is summarized in Exhibit 10. For more information on combustion, please see the chapter on Combustion.

Exhibit 10: Components of the Combustion Net Emission Factor for Vinyl Flooring ($MTCO_2E$/Short Ton)

Material/Product	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Combustion	CO_2 from Combustion	N_2O from Combustion	Avoided Utility Emissions	Steel Recovery	Net Emissions (Post-Consumer)
Vinyl Flooring	–	0.03	0.28	0.00	-0.61	–	-0.30

– = Zero emissions.

Note: Negative values denote net GHG emission reductions or carbon storage from a material management practice.

4.4.1 Developing the Emission Factor for Combustion of Vinyl Flooring

Raw Material Acquisition and Manufacturing: Because WARM takes a materials-management perspective (i.e., starting at end-of-life disposal of a material), RMAM emissions are not included for this materials management pathway.

Transportation to Combustion: EPA estimated GHG emissions from transportation energy use using data from FAL (1994).

CO_2 from Combustion and N_2O from Combustion: Vinyl flooring contains no nitrogen, and therefore, EPA estimates the emission factor for N_2O from combustion[2] to equal zero. EPA calculated CO_2 emissions from combustion based on the carbon contents of the PVC, vinyl acetate, and plasticizer components of vinyl flooring (38-, 49-, and 74-percent carbon, respectively).

Avoided Utility Emissions: Most Waste-to-Energy (WTE) plants in the United States produce electricity. Only a few cogenerate electricity and steam. In this analysis, EPA assumed that the energy recovered with municipal solid waste (MSW) combustion would be in the form of electricity, and thus, we estimated the avoided electric utility CO_2 emissions associated with combustion of waste in a WTE plant. Avoided utility emissions for vinyl flooring are negative. Exhibit 11 shows the calculation for the avoided utility emissions. EPA used three data elements to estimate the avoided electric utility CO_2 emissions associated with combustion of waste in a WTE plant: (1) the energy content of each waste material, (2) the combustion system efficiency in converting energy in vinyl flooring to delivered electricity,[3] and (3) the electric utility CO_2 emissions avoided per kilowatt-hour (kWh) of electricity delivered by WTE plants.[4] EPA took the energy content of PVC from FAL (2007, p. 1–12).

Exhibit 11: Utility GHG Emissions Offset from Combustion of Vinyl Flooring

(a) Material/Product	(b) Energy Content (Million Btu per Short Ton)	(c) Combustion System Efficiency (%)	(d) Emission Factor for Utility-Generated Electricity ($MTCO_2E$/ Million Btu of Electricity Delivered)	(e) Avoided Utility GHG per Short Ton Combusted ($MTCO_2E$/Short Ton) (e = b × c × d)
Vinyl Flooring	15.8	17.8%	0.22	0.61

Because avoided utility emissions are greater than the combined emissions from transportation and CO_2 from combustion, net GHG emissions for combustion are negative for vinyl flooring.

4.5 LANDFILLING

Landfill emissions in WARM include landfill methane and carbon dioxide from transportation and landfill equipment. WARM also accounts for landfill carbon storage and avoided utility emissions from landfill gas-to-energy recovery. Because vinyl flooring does not biodegrade, there are zero emissions from landfill methane, zero landfill carbon storage, and zero avoided utility emissions associated with landfilling vinyl flooring. Greenhouse gas emissions associated with RMAM are not included in WARM's landfilling emission factors. As a result, the landfilling emission factor for vinyl

[2] At the relatively low combustion temperatures found in MSW combustors, most of the nitrogen in N_2O emissions is derived from the waste, not from the combustion air. Because vinyl flooring does not contain nitrogen, EPA concluded that running these materials through an MSW combustor would not result in N_2O emissions.

[3] EPA used a net value of 550 kWh generated by mass burn plants per ton of mixed MSW combusted (Zannes, M. 1997), a MSW heat content of 10 million Btu per short ton, and a 5 percent transmission and distribution loss rate.

[4] The utility offset credit is calculated based on the non-baseload GHG emissions intensity of U.S. electricity generation, since it is non-baseload power plants that will adjust to changes in the supply of electricity from energy recovery at landfills.

flooring is equal to the GHG emissions generated by transportation to the landfill and operating the landfill equipment. The landfilling emission factor for vinyl flooring appears in Exhibit 12. For more information on landfilling, see the chapter on Landfilling.

Exhibit 12: Landfilling Emission Factor for Vinyl Flooring ($MTCO_2E$/Short Ton)

Material/ Product	Raw Material Acquisition and Manufacturing (Current Mix of Inputs)	Transportation to Landfill	Landfill CH_4	Avoided CO_2 Emissions from Energy Recovery	Landfill Carbon Storage	Net Emissions (Post-Consumer)
Vinyl Flooring	–	0.04	–	–	–	0.04

– = Zero emissions.

5. LIMITATIONS

The vinyl flooring emission factor EPA developed in this chapter is representative of VCT, not sheet flooring. To the extent that data were available, the factor is representative of current VCT manufacturing processes in the United States.

The life-cycle data EPA used to develop the emission factors for vinyl flooring were collected from various data sources because a literature search did not identify a complete, publicly available U.S.-specific dataset for vinyl flooring. In particular, EPA based the data used to evaluate the GHG emissions from manufacturing plasticizer and vinyl acetate and styrene-butadiene adhesive on European data; those data are representative of European practices. To address data quality issues arising from the use of a number of different data sources, EPA reviewed each source thoroughly to ensure that these data were high quality and applied in a manner that was consistent with WARM's life-cycle boundaries, and industry and life-cycle experts peer reviewed the final emission factors. Based on these quality-control checks and a review of the contribution of the European-specific data sets to the overall emission factors, EPA believes the overall impact on the final emission factor results is likely small.

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