Using WARM Emission Factors for Materials and Pathways Not in WARM

EPA's Waste Reduction Model (WARM) recognizes 54 material types, and that number continues to grow. However, users may still find that some materials and pathways of interest to them are not represented in the model. In such cases, WARM users often apply WARM factors for materials that seem similar to the non-WARM material in which they are interested. This document discusses some of the limitations of using WARM materials as proxies for non-WARM materials, and provides EPA-approved WARM proxies for some commonly-requested non-WARM materials.

Example uses of proxies

Users may wish to use WARM factors as proxies in three primary situations:

1. To model a **material** that is not in WARM, but is similar to a material that *is* in WARM. For example, using the personal computer recycling factor to represent recycling of all electronics.

2. To model a **different recycling pathway** for a WARM material. For example, modeling drywall recycled into fertilizer instead of a mix of new drywall and agricultural products.

3. To model a different material that follows a **similar recycling pathway** to a material that is recycled in WARM. For example, using the concrete-to-aggregate recycling factor to model other materials recycled as aggregate.

The suitability of proxies for any of these purposes will vary widely, depending on the specific life-cycle stages of the material and its intended proxy.

When are proxies okay and not okay to use?

When considering proxies, users should remember that similarity in materials' physical properties does not necessarily indicate that life-cycle energy use and greenhouse gas (GHG) emissions are the same. The processes used to create them, or manage them at their end-of-life, could be quite different.

For example, fiberglass insulation may share many physical properties with glass bottles (i.e., both are comprised largely of glass), but the processes used to make these materials, and to recycle them, are very different. Therefore, the recycling factor for glass bottles may not be a good proxy for recycling fiberglass.

Conversely, furnace slag and concrete may seem to be less closely related, but the concrete recycling factor is an acceptable proxy for recycling furnace

Why isn't my material in WARM?

EPA is committed to providing high-quality emission factors in WARM. Factors are developed using life-cycle inventory data from published studies or industry-specific contacts, along with robust analyses, and undergo an internal and expert review process. Users can therefore be confident about the quality of WARM estimates.

EPA is continually adding new materials to WARM; however, developing emission factors takes some time and is dependent on data availability. In 2010, EPA developed a new process for prioritizing materials to add; this process relies heavily on input from EPA Regions and other stakeholders, and is intended to help meet the needs of the majority of WARM users.

Sometimes, EPA would like to add a certain material to WARM, but the necessary data are simply not available. To maintain the integrity of WARM, EPA declines to develop factors when data and methodologies do not meet EPA's standards.

slag into aggregate. In this situation, the recycling pathways are fairly similar, partly because both offset virgin aggregate production.

To be a good proxy, materials should be similar in the processes related to:

- How materials are acquired;
- How the product itself is manufactured;
- The manner in which the materials are collected at their end-of-life; and
- The materials and processes that are offset when the materials are recycled.

EPA has developed a list of acceptable proxies, included in Appendix A.[1] To help illustrate how some materials may follow the life-cycle pathways of proxies more closely than others, EPA has also created a set of example diagrams that illustrate where along the life-cycle pathway the proxy pathways diverge from the WARM pathways. Please see Appendix B.

What are the benefits and drawbacks of using proxies?

An advantage of using proxies is that they help extend the use of WARM to cover more materials and pathways than those currently in the model.

Users should be aware of the drawbacks of proxy use, however. Although EPA strives to provide high-quality emission factors in WARM, there is already some uncertainty inherent in the factors due to the challenges of providing one-size-fits-all factors. Processes, transportation distances, landfill operations, etc. can vary by location and facility, and WARM cannot account for all these variations. Using proxies adds further (and potentially significant) uncertainty to WARM calculations, due to differences in the materials' life cycles.

Differences in processes may seem relatively minor on the surface, but they can have large impacts on the calculations. For example, if manufacturing processes represent a particularly energy-intensive part of an emission factor, then differences in the way materials are produced—such as using different fuel types, or relying on some different input materials— can significantly affect the resulting emissions.

In cases where the life-cycle stages of a WARM material are not a close match to the material of interest, it may be better to not model that material at all.

Why aren't more recycling pathways modeled in WARM?

You may be wondering what the benefits are for recycling , for example, glass bottles into aggregate used in kitchen countertops. You look to WARM and find that it indeed models recycling of glass bottles….but only to new glass bottles. Sound familiar?

Users sometimes wish to see more options for material recycling fates. It is WARM convention, however, to provide only one set of emission factors for each material.

Recycled materials are often aggregated at recycling centers, and distributed for use in various pathways. The person deciding to recycle often has little control over (or even knowledge of) how the recycled material is ultimately used. Therefore, WARM recycling factors aim to represent the common end-uses of the recycled materials.

[1] Use of these proxies may help WARM users understand the approximate GHG impacts of non-WARM materials or pathways. However, users should be aware that estimates developed using proxies may have a large degree of uncertainty associated with them. The list of acceptable proxies were developed using expert judgment, and proxies have not been quantitatively assessed or undergone extensive review.

Appendix A: List of Acceptable WARM Proxies

This table presents a set of acceptable material proxies; however, the list is not comprehensive. If a proxy does not appear on the list, it does not necessarily mean that it is unacceptable; please contact orcrWARMquestions@epa.gov if you have questions about the suitability of a proxy not listed here.

Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
Aggregate	Concrete	All available	Very Good	This proxy is suitable for any source of aggregate used to replace virgin aggregate. Concrete is a high-volume building material produced by mixing cement, water, and coarse and fine aggregates. In WARM, concrete is assumed to be recycled into aggregate, so the GHG benefits from the avoided emissions associated with mining and processing aggregate. However, WARM currently does not have data for the source reduction of concrete. Note: Steel slag and furnace slag used as aggregate would not require the same crushing processes as concrete or other materials recycled into aggregate, so this proxy would be considered "Acceptable" when modeling those materials.

Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
C&D Aluminum and other aluminum products	Aluminum Ingot	All available	Acceptable	In WARM, the aluminum ingot energy and GHG emissions factors could be used as a conservative proxy for representing aluminum materials other than aluminum cans, including electrical transmission and distribution wires, other electrical conductors, some extruded aluminum products, and/or aluminum product cuttings, joinings and weldings. The aluminum ingot material is also an acceptable proxy for products where aluminum alloy is used but the fabrication techniques are not clear or in a mixture. For instance, aluminum used in consumer durable products such as home appliances, computers, and electronics. However, using the aluminum ingot material type as a proxy for the aluminum materials mentioned above does not factor in the energy and emissions associated with the additional processing of aluminum ingot to produce a final aluminum product, which are likely to be quite significant. Thus, the resultant energy and GHG emissions impacts of managing aluminum products as represented by the WARM aluminum ingot factors likely underestimate the true impacts.
C&D Steel	Steel Cans	All available	Acceptable	The LCI data used to construct the "steel cans" material type represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans). Therefore, it may not exactly represent other Steel types but is an acceptable proxy.
Cabinets and doors	Wood Flooring	All available	Acceptable	Although the "Dimensional Lumber" material type could be used as a proxy, the "wood flooring" material type incorporates a hardwood flooring production stage, which may be similar to the cabinet or door processing stage.
Clean wood/pallets	Dimensional Lumber	All available	Very Good	The Dimensional Lumber material type is representative of wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two-by-fours.

Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
Coated paper	Magazines/Third-class Mail	All available	Good	Third-class Mail is now called Standard Mail by the U.S. Postal Service and includes catalogs and other direct bulk mailings such as magazines, which are made of coated, shiny paper.
Crumb rubber in asphalt binder	Tires	All available	Good	To the extent that recycled tires are used to displace ground rubber in asphalt binder, this is a good proxy.
Drywall-to: animal bedding, compost, fertilizer, soil amendment, etc.	Drywall	All available	Very Good	The drywall emission factor models the displacement of virgin gypsum by recycled drywall, for both agricultural and new drywall purposes. Assuming that the pathway recommended here represents displacement of virgin gypsum or recycled paper, the drywall factors are a Very Good proxy.
Electronic Media (CDs)	Mixed Plastics	All available	Acceptable	This proxy is suitable for plastic electronic media materials, such as compact discs. Since CDs are comprised largely of polycarbonate plastic, this is a suitable proxy. However, the 'mixed plastics' may cover different types of plastic not used for CDs.
Electronics	Personal Computers	All available	Acceptable	Electronics and PCs have similar components. However, the exact make-up of a given electronics can be very different than a PC, depending on the type of product.
Fats, oils, and greases	Food Waste	Source Reduction, Landfilling, Combustion	Acceptable	Upstream emissions from producing “fats, oils, and greases” may vary significantly depending on the material(s) from which they are derived. It is likely that "fats, oils, and greases" behave differently in landfills as oppose to other food wastes. Also, composting is not a suitable pathway for "fats, oils, and greases”.
Furnace slag-to-cement	Fly Ash	All available	Good	Since fly ash is also a byproduct that replaces cement, it can be used as a proxy in this situation.
High-grade Paper	Office Paper	All available	Very Good	Office paper represents paper made from uncoated bleached chemical pulp.

Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
Lamb and veal	Beef	All available	Acceptable	Emissions from production of different animal-based products can vary significantly based on differences in livestock characteristics, feed requirements, and production practices. As ruminants, lamb and veal production is likely to involve similar upstream energy and GHG emissions as beef production, making the beef factor an acceptable proxy for lamb and veal at this time.
MDF Cabinets for reuse	Medium-density Fiberboard	Source Reduction	Acceptable	Although the MDF material type in WARM will not incorporate the actual production of the cabinets themselves, using the source reduction pathway for MDF should be a good proxy for reuse of MDF cabinets.
Metal (type unknown)	Mixed Metals	All available	Good	Mixed metals are made up of 39% aluminum cans and 61% steel cans (based on 2010 data—this percentage is updated annually). This is an accurate proxy if the unknown metal type is a mixture of aluminum and steel.
Mixed Paper (primarily from offices)	Mixed Paper – Office Paper Definition	All available	Good/Very Good	Office mixed paper is assumed to be 21% newspaper, 5% corrugated containers, 36% magazines/third-class mail, and 38% office paper. If the mix of paper is close to this definition, then the proxy is Very Good. If the mix of paper does not resemble this definition closely, then the proxy is Good.
Mixed Paper (primarily residential)	Mixed Paper – Residential Definition	All available	Good/Very Good	Residential mixed paper is assumed to be 23% newspaper, 53% corrugated containers, 10% magazines/third-class mail, and 14% office paper. If the mix of paper is close to this definition, then the proxy is Very Good. If the mix of paper does not resemble this definition closely, then the proxy is Good.

Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
Mixed Paper (type unknown)	Mixed Paper – Broad Definition	All available	Good/Very Good	Mixed paper is assumed to be 24% newspaper, 48% corrugated containers, 8% magazines/third-class mail, and 20% office paper. If the mix of paper is close to this definition, then the proxy is Very Good. If the mix of paper does not resemble this definition closely, then the proxy is Good.
Organics (type unknown)	Mixed Organics	All available	Good	Mixed organics are made up of 51% food scraps and 49% yard trimmings (based on 2010 data—this percentage is updated annually).
Other Ferrous Metals	Steel Cans	All available	Good	Steel cans represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans). Steel is one type of ferrous metal (i.e., a metal that contains the element iron) and is the only ferrous metal modeled in WARM.
Other Non-Ferrous Metals	(Copper Wire * 0.5) + (Aluminum Ingot * 0.5)	All available	Good	Aluminum and copper are two types of non-ferrous metals. Other non-ferrous metals include lead and tin. To the extent that the material contains only copper and aluminum, this is a good proxy.
Other processed or prepared foods	Food Waste	All available	Acceptable	Many processed or prepared food products are likely to contain a mixture of individual food waste components available in WARM (grains, dairy products, fruits and vegetables, beef, and poultry) and others not currently modeled in WARM (caloric sweeteners, added fats and oils). A wide variety of ingredients are used in the many processed and prepared foods available in the United States; therefore, estimating upstream energy and GHG emissions from an individual food product in WARM involves a large degree of uncertainty. Due to this uncertainty, the "Food Waste" factor is an acceptable proxy at this time.
Other Yard Waste	Yard Trimmings	All available	Very Good	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.

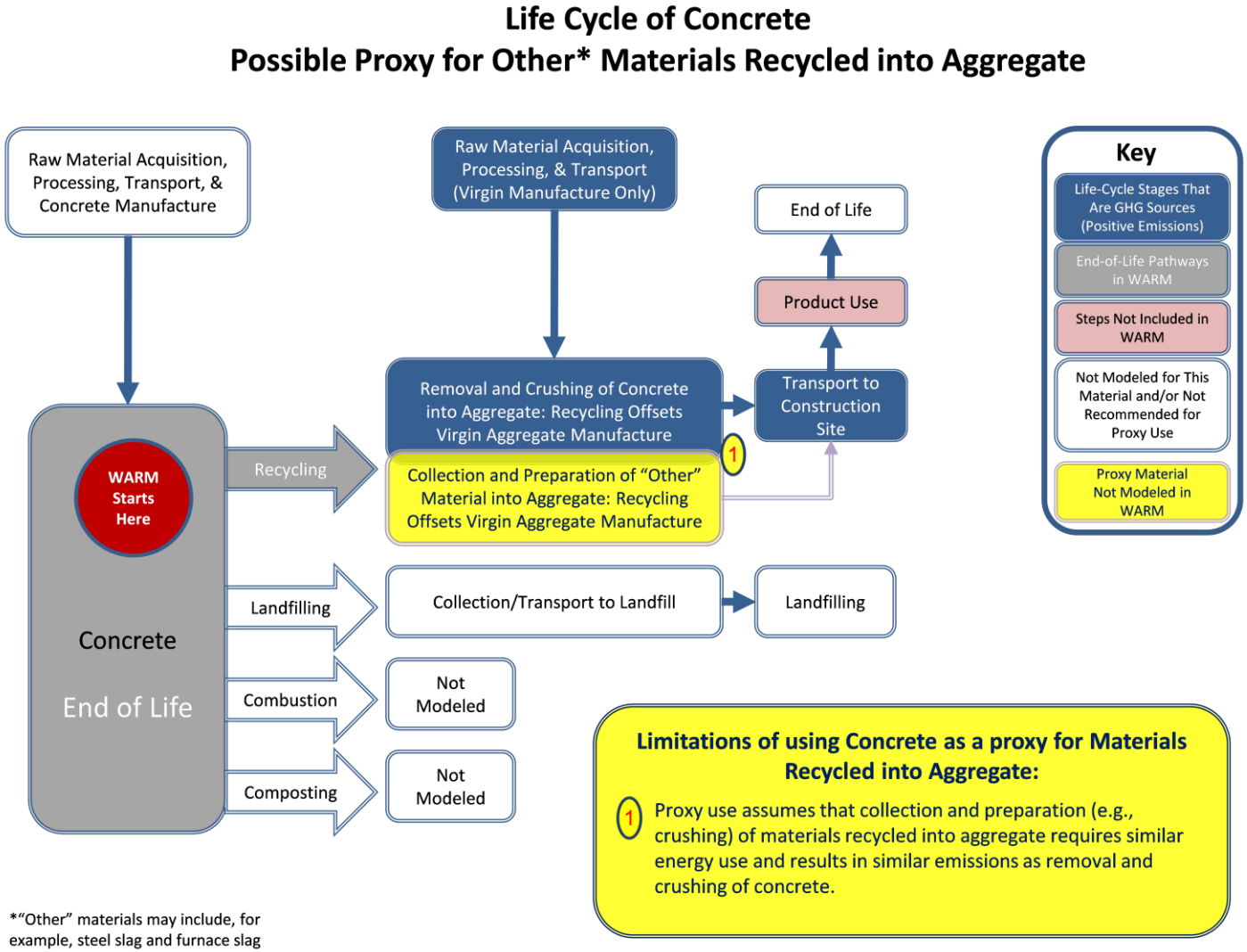
Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
Plastic (resin unknown)	Mixed Plastics	All available	Good	Mixed plastics are made up of 50% HDPE and 50% PET plastic based on the weighted average of the amount of total plastic recovered.
Plywood	Medium-density Fiberboard	All available	Very Good	The MDF material type is a panel product that consists of wood chips pressed and bonded with a resin. Plywood is an example of an MDF material.
Polypropylene	Mixed Plastics	Recycling	Acceptable	Although polypropylene is currently modeled in WARM, not enough data were available to develop recycling emission factors. For recycling, use mixed plastics, which are made up of 50% HDPE and 50% PET plastic based on the weighted average of the amount of total plastic recovered.. Although this is a different resin, it is an acceptable proxy for now.
Polystyrene	Mixed Plastics	Recycling	Acceptable	Although polystyrene is currently modeled in WARM, not enough data were available to develop recycling emission factors. For recycling, use mixed plastics, which are made up of 50% HDPE and 50% PET plastic based on the weighted average of the amount of total plastic recovered. Although this is a different resin, it is an acceptable proxy for now.
Pork	Food Waste	All available	Acceptable	Pork production is likely to require less upstream energy and GHG emissions than beef production but is somewhat more emissions-intensive than poultry production. Based on a survey[2] of available estimates of life-cycle production emissions for pork, the emissions are within the same order of magnitude as the "Food Waste" factor in WARM. Therefore, although the food waste factor represents a mix of foods and does not have a direct connection to pork production processes, this is an acceptable proxy to develop rough "order of magnitude" estimates for pork wastes.

[2] Hammerschlag, K. and K. Venkat. 2011. "Meat Eater's Guide to Climate Change & Health – Life Cycle Assessments: Methodology & Results." Environmental Working Group. Retrieved from: http://static.ewg.org/reports/2011/meateaters/pdf/methodology_ewg_meat_eaters_guide_to_health_and_climate_2011.pdf?_ga=1.144155635.732812262.1425505183.

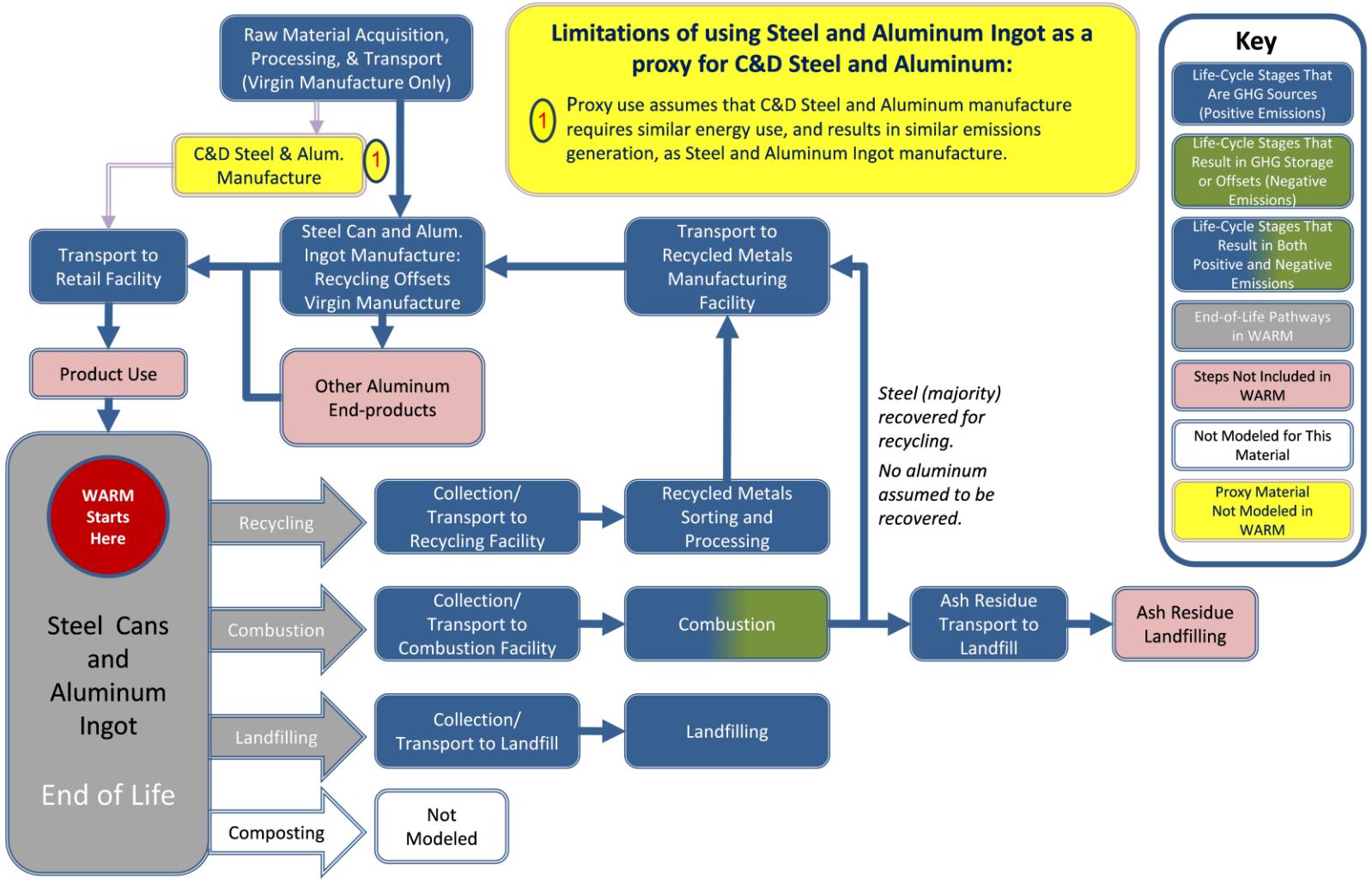
Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
PVC/Vinyl	Mixed Plastics	Recycling	Acceptable	Although PVC is currently modeled in WARM, not enough data were available to develop recycling emission factors. For recycling, use mixed plastics, which are made up of 50% HDPE and 50% PET plastic based on the weighted average of the amount of total plastic recovered. Although this is a different resin, it is an acceptable proxy for now.
Seafood	Food Waste	All available	Acceptable	Seafood production is likely to require less upstream energy and GHG emissions than beef production but is somewhat more emissions-intensive than poultry production. Based on a survey[2] of available estimates of life-cycle production emissions for seafood has found that the emissions are within the same order of magnitude as the "Food Waste" factor in WARM. Therefore, although the food waste factor represents a mix of foods and does not have a direct connection to seafood production processes, this is an acceptable proxy to develop rough "order of magnitude" estimates for seafood wastes
Tires-to-fuel	Tires	Combustion	Very Good	This is modeled in the combustion pathway for tires.
Turkey and other non-chicken poultry	Poultry	All available	Acceptable	The "poultry" factor in WARM is based on broiler chicken product, but due to similarities in production practices, it is a good proxy for other poultry meats beyond broiler chicken.
Various/general materials	Mixed Recyclables	All available	Acceptable	This category is too broad to assess the materials it encompasses, but mixed recyclables will likely cover many of the materials included in this category.
Wood (General)	Dimensional Lumber	All available	Acceptable	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.

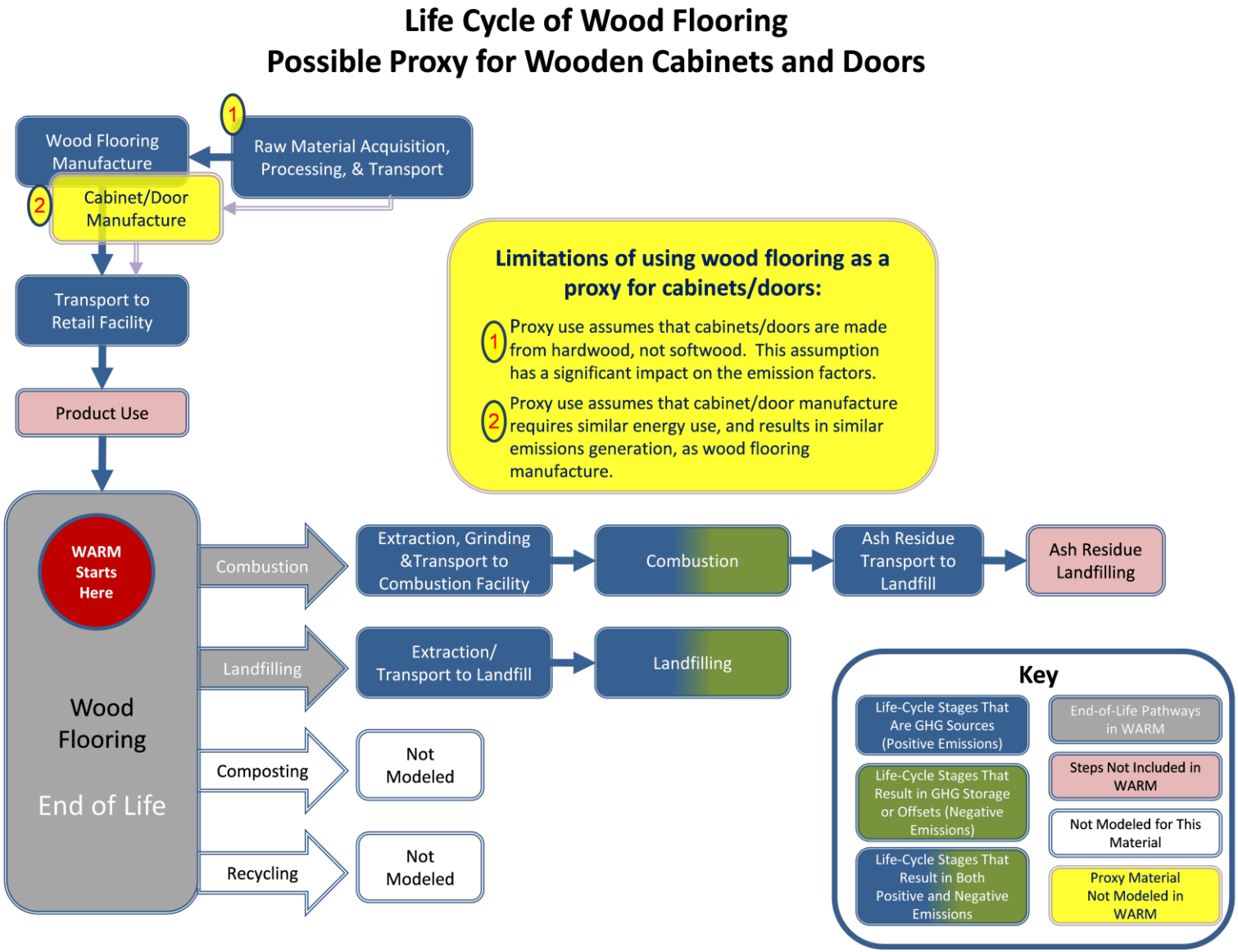
Available WARM Proxies, and Relative "Suitability" of that Proxy (based on expert judgment)				
Material	**Associated WARM Emission Factor**	**Pathway(s)**	**Relative Suitability* of Proxy (Very Good, Good, Acceptable)**	**Comments (why it is ranked the way it is)**
Wood for fuel	Combustion factor for dimensional lumber	Combustion	Very Good	Dimensional lumber is a very good proxy if the wood is being combusted to generate electricity. Because the emission factor accounts for avoided utility emissions, it would NOT be a good proxy for other wood burning purposes, such as for heating a home. Depending on the type of wood being burned, MDF or wood flooring could also be suitable proxies.

Appendix B: Life-cycle Illustrations of Proxies



Life Cycle of Steel Cans and Aluminum Ingot
Possible Proxy for C&D Steel and C&D Aluminum




Life Cycle of Wood Flooring
Possible Proxy for Wooden Cabinets and Doors
1
Wood Flooring Manufacture
Raw Material Acquisition, Processing, & Transport
2
Cabinet/Door Manufacture
Transport to Retail Facility
Product Use
Limitations of using wood flooring as a proxy for cabinets/doors:
1 Proxy use assumes that cabinets/doors are made from hardwood, not softwood. This assumption has a significant impact on the emission factors.
2 Proxy use assumes that cabinet/door manufacture requires similar energy use, and results in similar emissions generation, as wood flooring manufacture.
WARM Starts Here
Wood Flooring
End of Life
Combustion
Extraction, Grinding &Transport to Combustion Facility
Combustion
Ash Residue Transport to Landfill
Ash Residue Landfilling
Landfilling
Extraction/ Transport to Landfill
Landfilling
Composting
Not Modeled
Recycling
Not Modeled
Key
Life-Cycle Stages That Are GHG Sources (Positive Emissions)
Life-Cycle Stages That Result in GHG Storage or Offsets (Negative Emissions)
Life-Cycle Stages That Result in Both Positive and Negative Emissions
End-of-Life Pathways in WARM
Steps Not Included in WARM
Not Modeled for This Material
Proxy Material Not Modeled in WARM