PLACE BASED PAINT MAKING

Transitioning away from acrylic paints in the artist studio is crucial to establish studio practices that reduce or even eliminate reliance on fossil fuel-based materials, and detrimental mining practices which are harming human and biosphere health.

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01

THE PROBLEM

The commercially made materials used in artist and maker studios have significant impacts to human and biosphere health such as land stress, water stress, habitat destruction, socio-economic disparities, acidification, and microplastic pollution, to name a few.

These consequences are interconnected with the production, use, and disposal of these materials in artistic and creative processes, emphasizing the far-reaching implications of material choices on multiple levels.

The disconnect between the artist and their materials is causing negative effects on human and biosphere health.

Source: Canva

02

DEFINING THE PROBLEM

The following pages lay out the process of defining the problem through:

- Research
- Observation
- Analysis
- Organization & Synthesis
- Description

Source: Canva

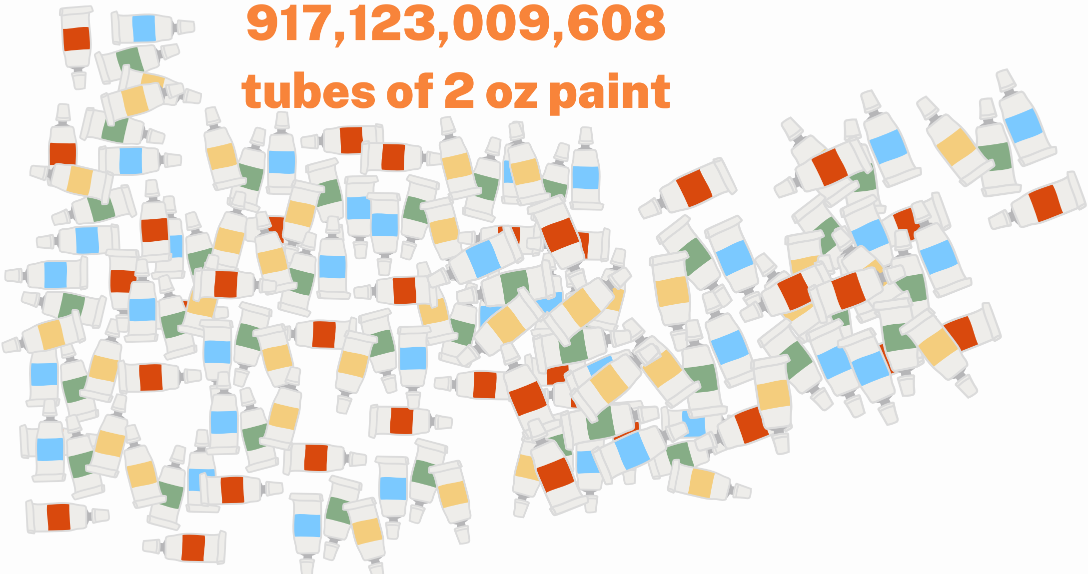
02 Defining the Problem

RESEARCH

52 million tonnes of paint

produced every year.

If we were to convert 52 million tonnes of paint to something easier for an artist to visualize such as a tube of paint, it would equal:

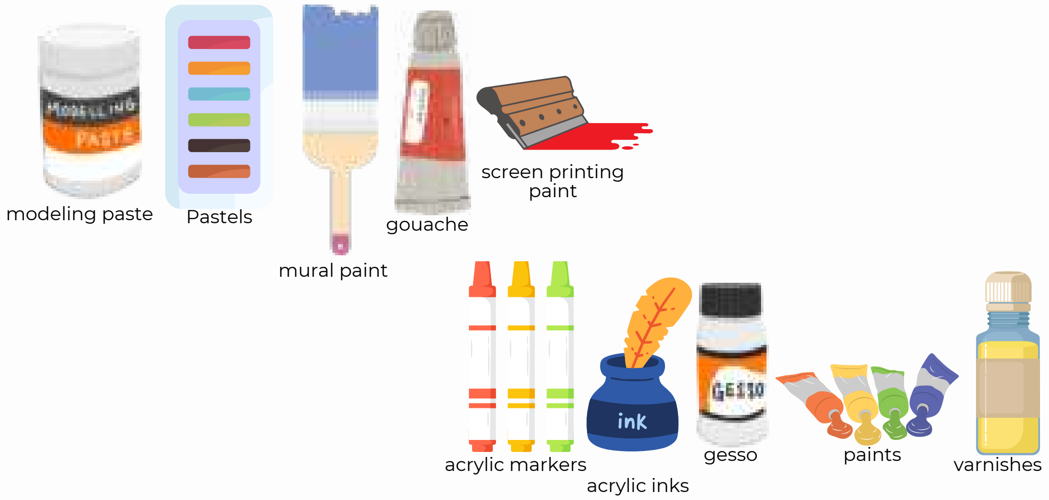


917,123,009,608

tubes of 2 oz paint

This is across industrial and commercial industries.

Here are only some of the materials found in an artist studio which commonly contain an acrylic polymer binder

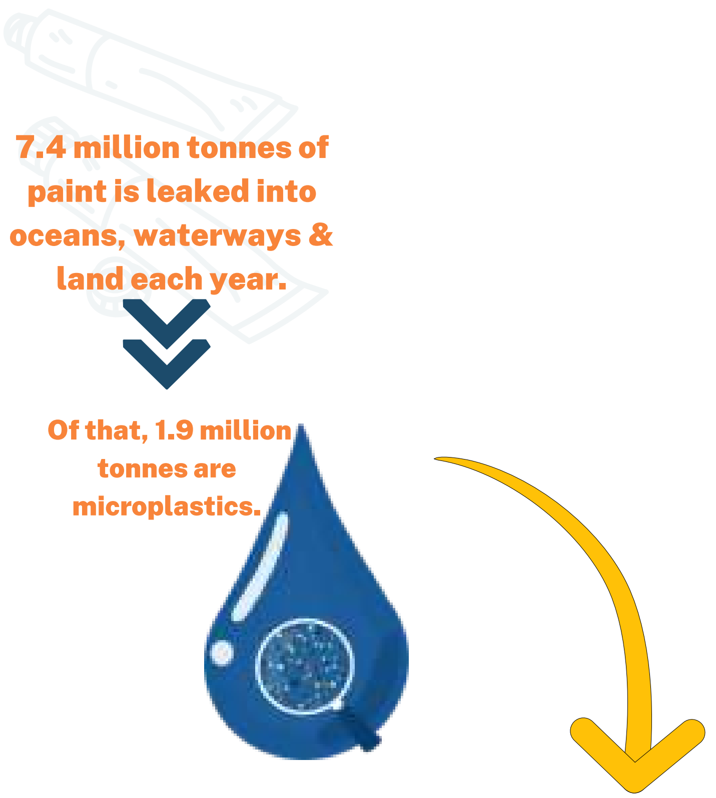


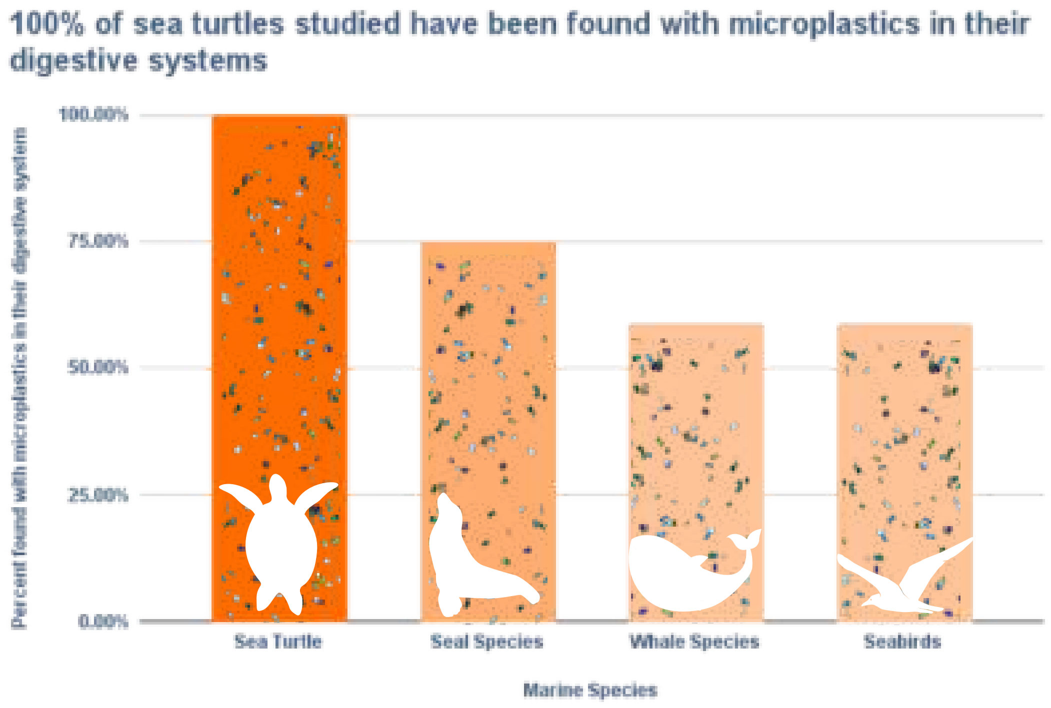
Acrylic paints gained popularity in the 1950s for home and furniture painting, and soon became manufactured by artisan and commercial brands for the crafter to the professional. Acrylic paints, which are commonly synthetic pigments mixed in an acrylic polymer emulsion, are petroleum-based and widely used in artist studios, art schools, and various art programs.

The creation of acrylic paints, synthetic pigments and packaging are petroleum based materials contributing to global plastic production, which has dramatically increased in recent years to over 368 million metric tons in 2019 and contributing to 4 percent of global greenhouse gas emissions in 2015 as stated by Project Drawdown.

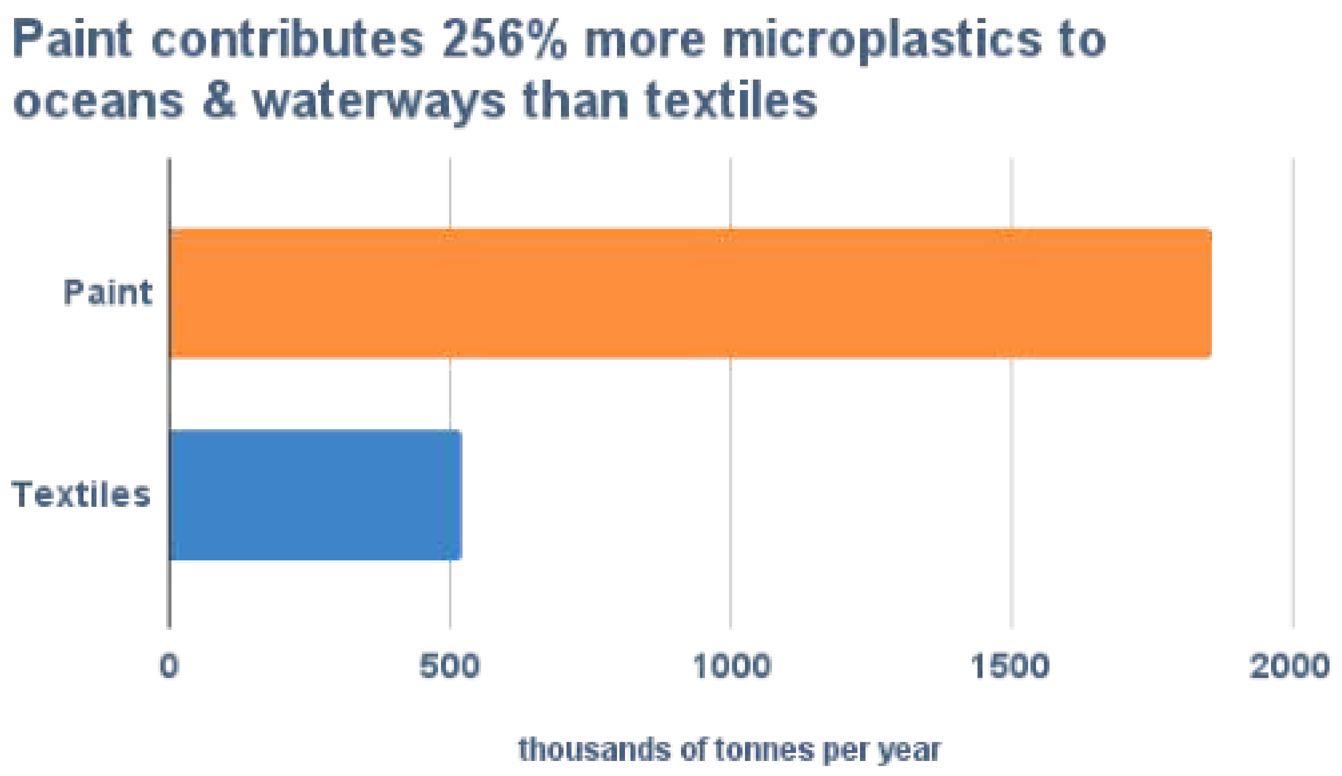
Mining of minerals for the pigments plays a significant role in paint production, particularly for colors like titanium dioxide, ochres, cadmium, and cobalt. However, mining has long-term ecological damage and profound social impacts such as displacement and pollution according to Earth.org.

RESEARCH





According to a recent study by Environmental Action, even though these paints are said to be safe to dispose of down the drain because they are water based, the disposal of these materials contribute to microplastic contamination in waterways measuring over 3 times greater than the threat of textiles.



RESEARCH

The first pigments were created by prehistoric artists 40,000 years ago, who used a mixture of soil, animal fat, minerals, charcoal, and chalk to paint the walls of their caves.[3]

In just the last 200 years, compared to the several thousand that humans have been painting, the advancements that have been made in science have completely disconnected the artist from the natural world to the point where they don't know where their paints come from, nor do they know what the actual impact of their choices are making on the health of humans or the biosphere.

More details on this history can be found in Appendix B.

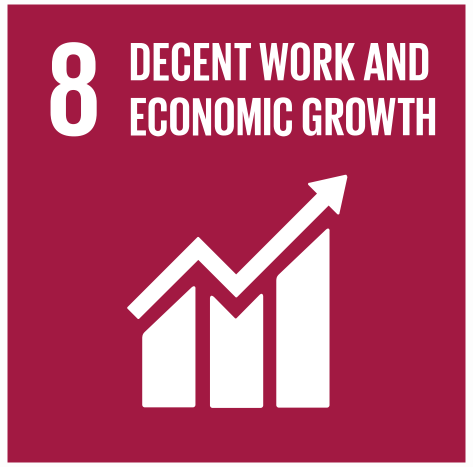
Da Vinci's Studio at Le Clos Lucé 1515-1519

THE GLOBAL GOALS

UN SDGS

From the research, the focus of this project will center on three main global Sustainable Development Goals from the UN:

Goal 12 is about ensuring sustainable consumption and production patterns, which is key to sustain the livelihoods of current and future generations.



Goal 8 is about promoting inclusive and sustainable economic growth, employment and decent work for all.

Goal 14 is about conserving and sustainably using the oceans, seas and marine resources. Healthy oceans and seas are essential to human existence and life on Earth.

02 Defining the Problem

OBSERVATION

THE ARTISTS

Seven artists were interviewed in their Twin Cities studios to uncover the reasons they prefer using acrylic paints.

These matrices reveal results of their interviews and studio tours.

Common reasons why they use acrylic based paints:

- got used to it and stuck with it - less intimidating than oils
- dries fast
- affordable
- easily accessible
- can clean with water (although in the Research phase we learned this isn't safe for the environment and shows how artists are unaware of the impacts to the biosphere and human health).
- less smell than oil painting
- opaqueness

Each color represents one of the artists.

Key Takeaways:

1) The data shows that most artists have little to no experience in making their own paints so there's an opportunity there. However, making your own paints may mean that the consistency is different or they may work differently or need a different substrate.

2) These artists don't always stick to the same style and they are trying new materials so they may be open to some experimenting

3) These artists are looking for inexpensive material choices.

4) At least half of these artists are at least considering sustainability in their studio practice, so they might be open to more sustainable ideas for their studio.

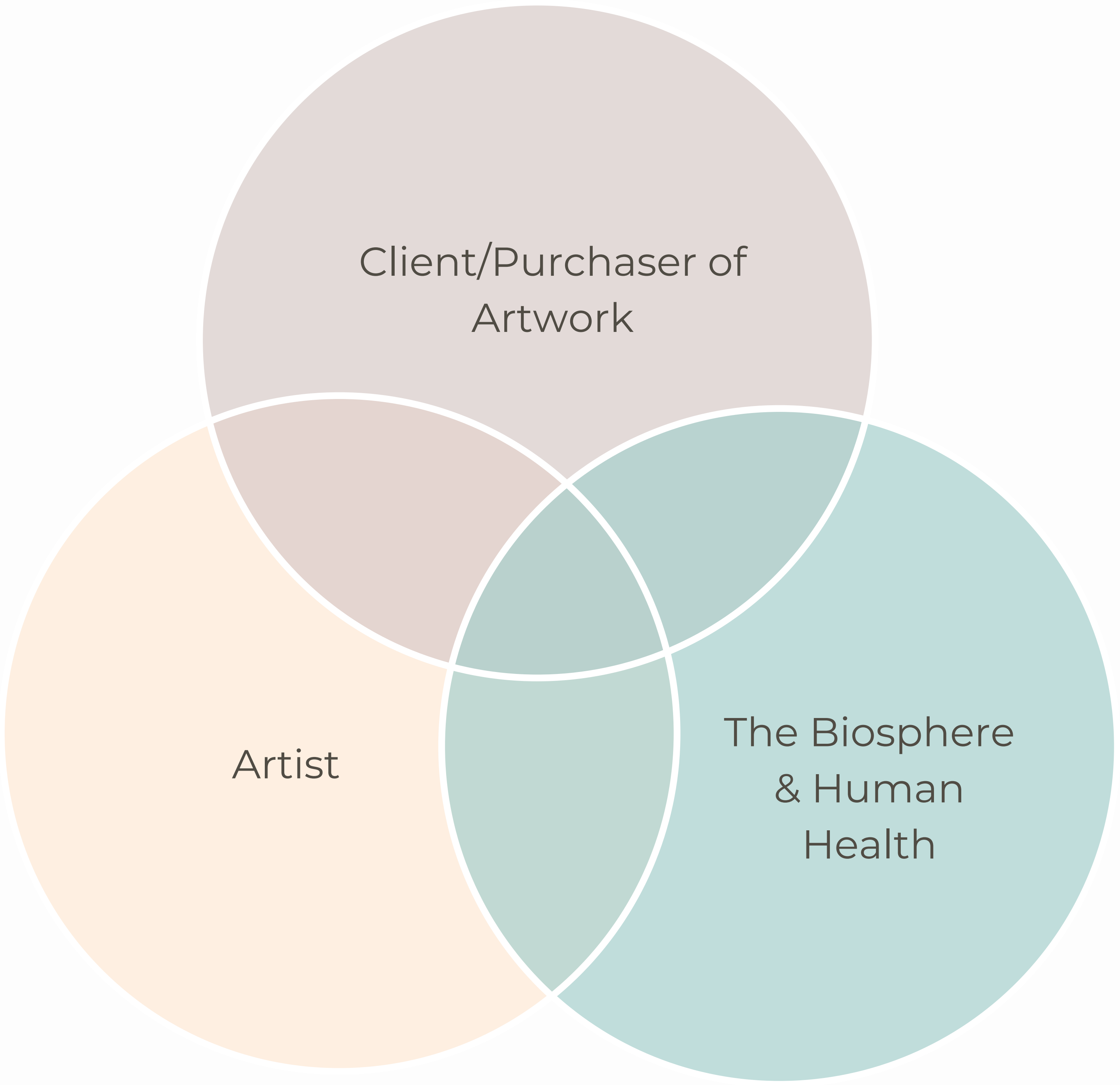
OBSERVATION

THE STAKEHOLDERS

Who are the actual stakeholders for an artist when they are creating an artwork?

Stakeholders:

- The Artist - in this case we are looking at professional artists.
- The Client/Buyer - these artists rely on making a living selling their work so the client/buyer is an important stakeholder. Transparency about the materials: why the artist uses what they do and stories around it will be important= Creating a narrative. For future growth, it's important to consider alternative opportunities for financial growth for the artist that align with their values such as grants, sharing knowledge, partnerships, etc...
- The Biosphere & Human Health- the current actions of using acrylic paints is having a significant effect on the biosphere & human health.



Stakeholders

02 Defining the Problem

ANALYZE

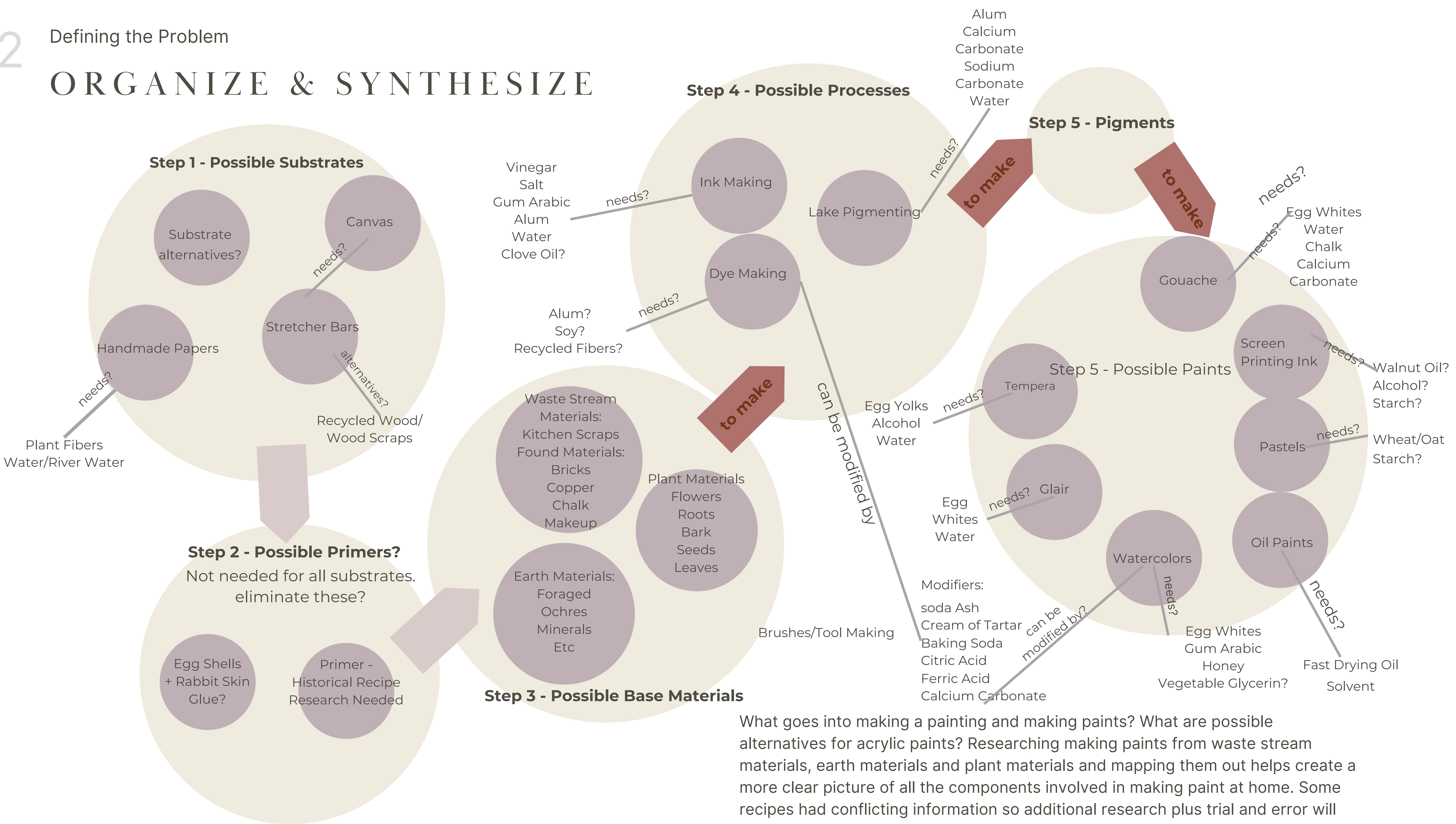
Is it possible to eliminate acrylic paint materials in the artist studio and shift to having artist make their own paints from more sustainable materials?
SWOT Analysis based on the research and observations.

Strengths • Able to create a clean supply chain and design out acrylic and petroleum based materials • Cleaner health in the studio • Cleaner health for the environment • More hands on engagement with their art • More hands on engagement with nature • Better understanding of from what their art is made • Potentially more perceived value for the client if marketed correctly • Better branding/marketing in a oversaturated market place to stand out as an artist that makes their own materials	**Weaknesses** • Unlikely to be exactly the same as mass produced acrylic paint • Artists might not want to spend the time making their own paints • Some artists are taught that they have to use professional brands to be a professional artists so they might not even be willing to try • Might not want to experiment, too attached to their own style. • Color limitations • Longevity/lightfastness of colors?
Opportunities • Often, when limiting supplies is when the best innovations happen. So what if the paints are different and there isn't an equivalent to acrylic, or neon pink is no longer available? What CAN be created? What new creations can one make with the new limitations? What new styles will happen. • Do paintings, or creations for that matter, HAVE to last forever? So what if the colors aren't lightfast, or they change color over time. What does that mean? • Can art be created that can be returned to the earth without damaging it? What does that look like?	**Threats** • The Mona Lisa - The mindset that every artist is creating work that will end up in galleries for centuries like the Mona Lisa and be traded in auctions forever. When in reality, most of it will eventually end up in a landfill. Trends change, and styles change, and people die, and what happens with the artwork they buy today? • How likely is acrylic to be eliminated off the shelves? • People's increased desire for convenience. • Art schools only teaching with materials from the art store. • Fast-consumerism. • Unwillingness to change.

Takeaways

- With limits comes creativity. If going to an art supply store and having all the choices is no longer an option, and only being able to use what you can make is the new limitation, artists will have to lean into their creativity with limited materials. New, exciting artwork could emerge.
- Artists who work primarily with acrylics may need to rethink their art when shifting to a different medium. Just as it would be if they shifted to watercolors or charcoal as a primary medium. There's a learning curve. The art they made with acrylics won't be able to be the same in the new medium. But this doesn't mean they lose their "style", and it opens the door to new opportunities.
- There's as much of a mindset/behavior change for the artist as there is an education on more sustainable materials.
- There's a lot of teachings on art technique, but very little on art materials, other than what materials to buy. There's a disconnect between artist and their materials.
- Exploring more sustainable art materials could help them stand out in a crowded art market.
- Some acrylic artists may not be willing to make a change.

ORGANIZE & SYNTHESIZE



What goes into making a painting and making paints? What are possible alternatives for acrylic paints? Researching making paints from waste stream materials, earth materials and plant materials and mapping them out helps create a more clear picture of all the components involved in making paint at home. Some recipes had conflicting information so additional research plus trial and error will help narrow down what is necessary and what isn't for successful recipes.

DESCRIBE

Key Design Drivers

- Ingredients should be sourced locally (within 25 miles of the city of Minneapolis for this author). This creates a local area parameter for exploration for the project.
- Ingredients should not be synthetic in nature whenever possible. Tracing supply chains will be important for this research.
- Recipes need to be something that can be made in a kitchen, not dependent on elaborate equipment. Artists will likely not want to invest in expensive lab equipment. Being able to make paint with what is already on hand will be important for an artist's willingness to try these recipes
- The recipes need to create paints an artist would use, and should be water-based media, like acrylic paint.
- Through the creation process, waste needs to be able to be returned to the earth safely. Nothing should be considered hazardous waste.
- Materials need to be inexpensive since this was a common reason artists preferred acrylics.
- Resulting paints must not have an off-putting smell since this was a common reason artists preferred acrylics.
- Recipes must be simple and easy to learn.

Key Design Objectives & Potential Sustainable Design Strategies

- Consider Future Generations
  - Design for the 7th Generation
- Create "green" jobs
  - Buy locally-made, artisan-made materials
- Design for connection with nature
- Comply or exceed compliance
  - Meet or exceed standard environmental practices
- Optimize Resources
  - Incorporate Recycled Content
  - Localization
- Work Within Living Systems
  - The Natural Step
- Source Responsibly
  - Source sustainably-managed renewable resources
  - Source from vendors who meet or exceed standard environmental practices
  - Source local materials
- Renew Resources
  - Use annually-renewable or rapidly renewable materials
- Optimize Material Health
  - Eliminate or avoid toxic materials
  - Inventory and assess the impacts of the chemistry of a material over the lifecycle
- Consider the complete lifecycle performance, not just one phase
- Cycle Resources
  - Design for Composting
- Cause no harm, create no new problems - Precautionary Principle

03

DIVERGENT THINKING

The following pages include various divergent thinking exercises:

- Mind Mapping
- List Making
- Gap Filling
- Attributing Change

Source: Canva

KEY CHALLENGES

Looking for opportunities in How might we...? statements.
These questions are explored through the following brainstorming exercises.

Key Challenge 1:
Popularity of acrylic paint from the art store

How might we make paint in the home instead of going to the art store?

How might we source only locally available natural materials instead of commercially available?

Key Challenge 2:
Reliance on fossil fuel derived materials in many artist materials

How might we make art without using petroleum based materials?

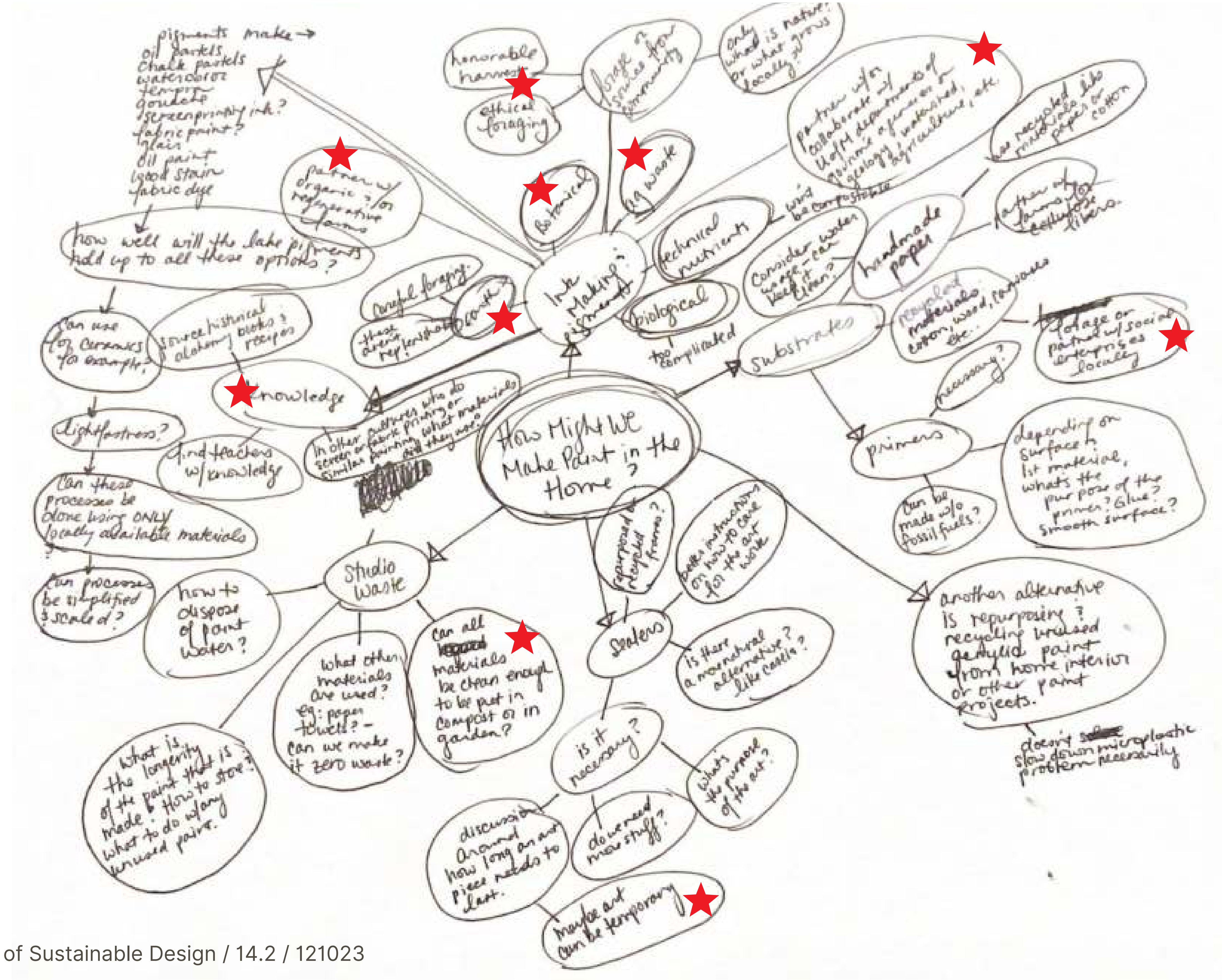
How might we make art without harming the biosphere?

BRAINSTORMING

★ = possible ideas to follow up on

Exercise 1: Mind Map

How might we make paint in the home?

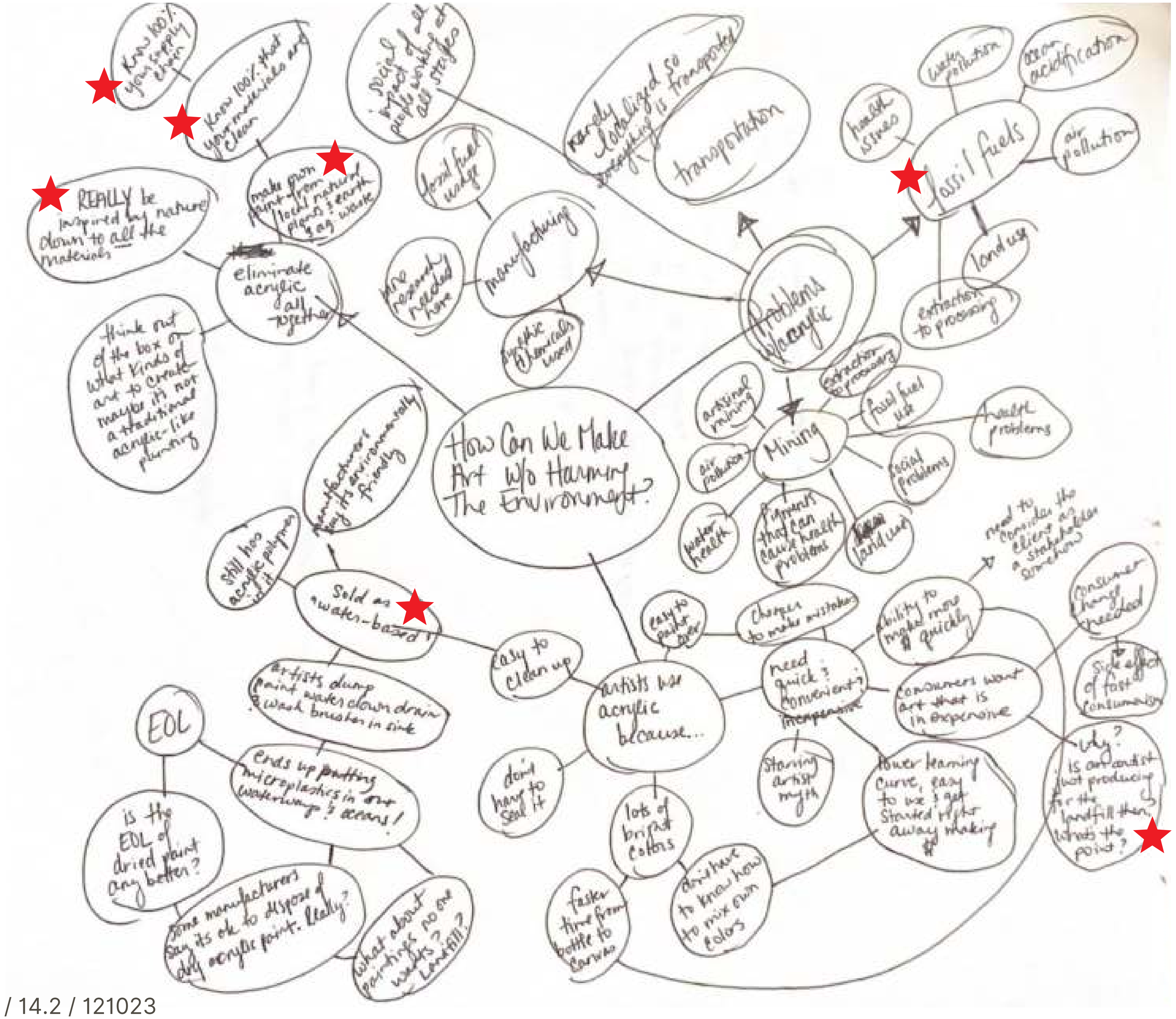


03 Divergent Thinking

BRAINSTORMING

Exercise 1: Mind Map

How can we make art without harming the biosphere?



03 Divergent Thinking

BRAINSTORMING

Exercise 1: List Making

How might we make art without harming the biosphere?

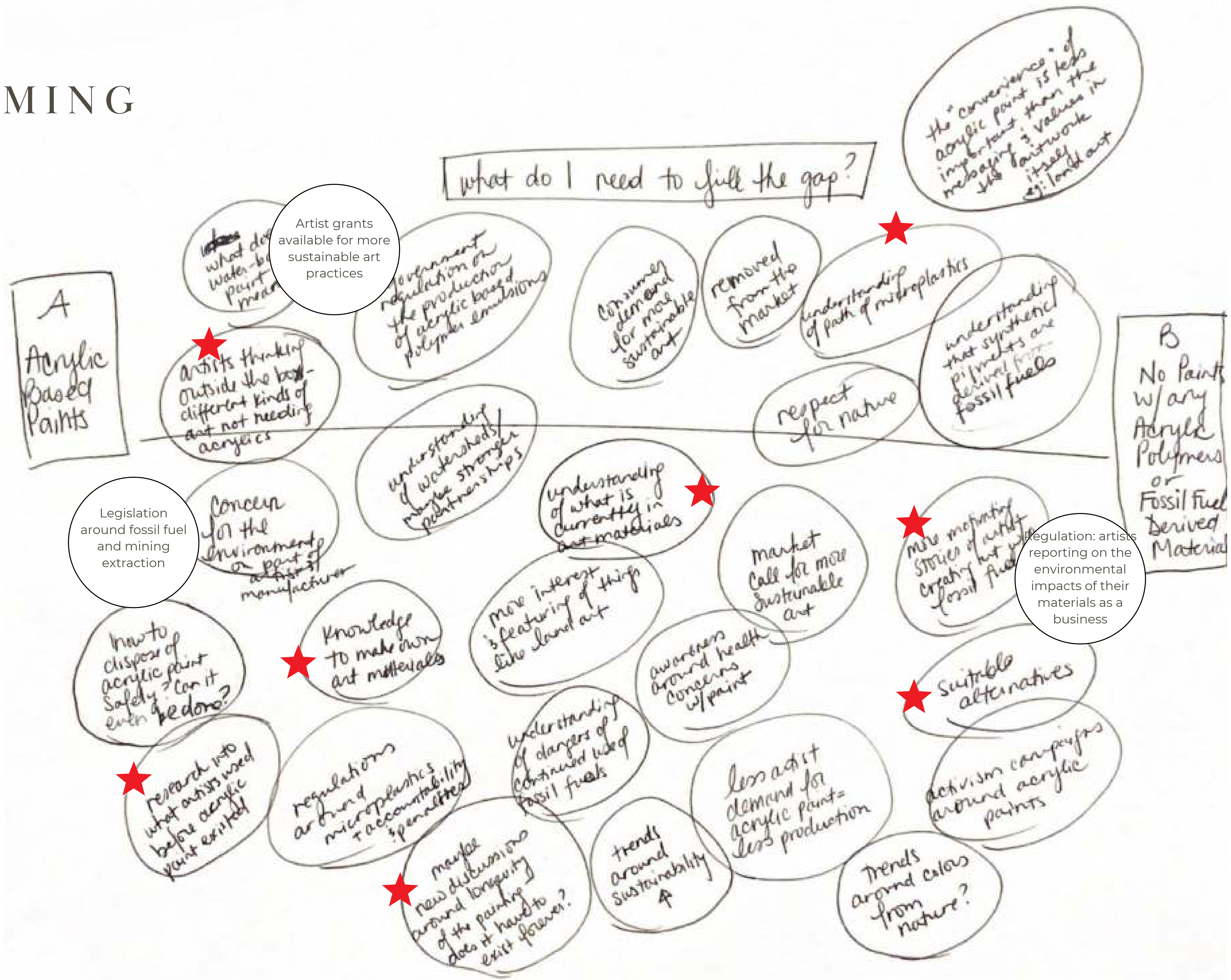
- Use natural resources to make materials
- eco art supplies
- pigments
- stone
- clay-wild clay
- from nature
- sourcing materials from abundant resources & renewable
- use invasive species
- harvesting/foraging
- performance art
- singing/music
- materials & processes
- land art
- make own art materials
- involving nature in the art process
- shifting perception of the gallery of art = money
- materials are compostable
- eliminate petroleum based materials all together
- low VOC materials
- materials data sheets for all materials used in process
- make Mother Nature a stakeholder - give her a seat at the table
- water after use in studio must go back out just as clean
- handmade from sustainable sources
- anthotype art
- shifting artist mindset to make nature a priority
- studying more ancient & historical art - how was it done in the past?
- Repair/salvage previous art or materials into new work
- No waste rule in studio
- How can studio waste become food for something else?
- Can some of the materials be from the waste stream of another place? eg" used coffee grounds to make ink from a local coffee shop?
- Replace synthetic pigments with non-petroleum derived pigments
- Replace chemicals with a plant alternative
- Art that has utility-purpose-usefulness
- Botanical dyeing
- Connecting with nature
- Partnering/collaborating with entities with Watershed who would have environmental input in the process.

03 Divergent Thinking

BRAINSTORMING

Exercise 1: Gap Filling

What do I need to fill the gap from
A: Acrylic based paints to
B: No Paints with any acrylic polymers or crude oil derived materials?



BRAINSTORMING

Exercise 1:
Attributing Change

What was used before acrylic paint?

- First art was mostly locally available ochres (earth pigments) & water in caves to tell stories of local events/people animals
- Charcoal easy to make from wood/vines in a fire.
- Brushes were fingers, hands or made from plants or materials found in nature.
- ★ Inks are easy to make - carbon black is essentially black carbon from the fire. Lamp black was teh black soot from oil lamps. Can get blacks from some plants
- ★ Egg shells can make a white ink & watercolor (but not a pure white paint)
- ★ Artists who created illuminated texts created paints using pigments with egg whites and honey
- ★ Tempera paint used with gold leaf on icon paintings on wood used egg yolks with pigment and a bit of alcohol
- Gilding used, still to this day, rabbit skin glue, clay bole in gold or red (ochres & 24k gold) often on wood or plaster.
- ★ Fabric dyeing used botanical materials long before anything synthetic was created. Weld, wood and madder root along with indigo are still incredibly popular & cover the primary color bases of yellow, blue and red. All of these can be made into inks & pigments as well.
- Buckthorn was also used to make Dutch Pink (a yellow color) for painting. In some areas Buckthorn is considered invasive.
- Quills were used as a pen for inks.
- Papers were made by hand using cellulose fibers
- Interior paint was milk paint, lime plaster or casein paint.

BRAINSTORMING

POSSIBLE IDEAS TO FOLLOW UP ON

- Ink & Pigment making from Botanical, Agricultural Waste and/or Earth (natural materials & only from abundant and renewable sources). Also consider invasive species.
- Honorable Harvesting/Ethical Foraging.
- Partnerships/Collaborations with organic and/or regenerative farms, as well as geologists, watershed organizations, agricultural organizations and local social enterprises.
- Get knowledge from teachers of ink & pigment making, source historical alchemy books & recipes, and research into other cultures who made their own paints for various hand making skills.
- Connecting/Respecting nature.
- If an artist is just creating inexpensive art for the masses, are they just creating for the landfill? Is this an result of consumerism and our current economic system?
- Can all materials be clean enough to be put in compost or in the garden from the studio?
- Consider maybe art can be temporary & doesn't have to exist forever.
- Explore the concept of land art within the context of this project. Does the messaging and values of sustainable art outweigh the convenience of acrylic paint?
- Making the environment a stakeholder in the art making process & making it a priority.
- Consider educational components: What does water-based paint mean? What are the problems with fossil fuel based materials?
- Share stories of artists creating work without the use of fossil fuels = motivation and inspiration.

04

LIFECYCLE PROCESS & FLOWS

To understand where to intervene in a system for the biggest impact, it's important to look at the system as a whole.

The following pages illustrate the lifecycle of acrylic paint, and thinking through the best stages to intervene for maximum impact.

Appendix A includes additional detailed research of acrylic polymer binders, titanium dioxide (the most common mineral in paint) and quinacridone (a very popular family of synthetic pigments in paint)

Source: Canva

LIFECYCLE OF ACRYLIC PAINT

Raw Material Extraction
from Horizontal Drilling or Hydraulic Fracturing

Inputs
- water & chemical
- fuels for machinery
- labor

Outputs
- wastewater & tailings w/possible heavy metals and radioactive materials stored in underground wells or open-air pits that can lead or overflow contaminating aquifers
- land use & stress on natural ecosystems
- destruction of vegetation & soils
- emissions from heavy equipment
- frequent oil leaks
- habitat destruction
- community evacuation
- **PRODUCT: crude oil**

Material Processing
Fractional Distillation & Chemical Processing at Refinery

Converting Naptha through additional polymerization and compounding/processing to acrylic polymer

Inputs
- PRODUCT: crude oil
- energy from coal to power refinery
- labor

Outputs
- **PRODUCTS:** Refinery Gases, Kerosene, diesel, gasoline blending components, **naphtha**, lubricating oils, kerosene, residual fuel oil, refinery gases
- **SECONDARY PRODUCT from naptha: Acrylic polymer**
- reduced access for local people to uncontaminated fresh water supplies
- pollutants = cancer causing benzene, particulate matter, nitrogen oxides, carbon monoxide, sulphur dioxide.
- Refinery pollution contributes to existing racial & socioeconomic health disparities due to location of the refineries
- dangerous work around chemicals
- dangers of fires
- acid precipitation & acidification
- health risks from living near refineries

Paint Creation

Inputs*
- pigments: For example Titanium Dioxide from dry or hard rock mining and processed through a chloride process, and Quinacridone a synthetic pigment derived turpentine. *Lifecycle details in Appendix on both of these pigments.*
- additives
  - Plasticizer (petroleum derived)
  - Stabilizer/Surfactant
  - Solvent (petroleum derived)
  - Thickener/Thinner
  - Preservatives/Biocides
  - Dispersants
- labor

Outputs
- **PRODUCTS: Acrylic Paint**
- Energy from coal to power manufacturing plant

Packaging.

Inputs
- acrylic based tubes or bottles and tops
- labor

Outputs
- **PRODUCTS: Commercially packaged acrylic paint**
- Energy from coal to power manufacturing plant

Transport
to paint making plant + to retailer + to studio (at minimum)

Inputs
- fuels for machinery
- labor

Outputs
- microplastics from tires on road
- air pollutants: particulate matter, nitrogen oxides, volatile organic compounds from vehicles, suspected to cause cancer

In Studio Use

Inputs
- water
- paper towels
- paint brushes
- canvas or other substrates
- other paint mediums (optional)
- energy from coal for the studio lights
- labor

Outputs
- **PRODUCTS: artwork**
- paper towel/rag waste
- acrylic paint water waste
- microplastics
- acrylic paint waste
- packaging waste (unused, dried up and/or empty paint tubes)

EOL

Landfill
- paint tubes, used brushes, rags, paper towels, artwork

Hazardous Waste
- left over paint and paint tubes

Leaching
- Microplastics leaching to oceans and waterways affecting oceanlife health

*Very difficult to obtain exact information. These are generalizations.

NATURAL STEP SYSTEMS CONDITIONS

Systems Condition 1

“In order for a society to be sustainable, nature’s functions and diversity are not systematically subject to increasing concentrations of substances extracted from the earth’s crust.”

This lifecycle diagram shows that acrylic paint is heavily reliant on mining both of crude oil and of minerals. The best place to intervene in this system is to eliminate the use of industrial mining and the use of crude oil.

Systems Condition 2

“In order for a society to be sustainable, nature’s functions and diversity are not systematically subject to increasing concentrations of substances produced by society.”

The outputs shown in the diagram reveal pollutants such as cancer causing benzene, particulate matter, nitrogen oxides, carbon monoxide, sulphur dioxide at the manufacturing stage. As well as heavy metal and radioactive materials in the waterways in the extraction stage, and suspected cancer causing air pollutants at the transportation stage. This leave plenty of opportunities for intervention.

Systems Condition 3

In order for a society to be sustainable, nature’s functions and diversity are not systematically impoverished by physical displacement, over-harvesting or other forms of ecosystem manipulation. “

Deep-sea drilling for crude oil has the potential of exploding, leaking or spilling oil into the ocean. Oil Extraction (land and sea) has a devastating effect on habitats. Mining can cause water acidification, soil erosion and the degradation of local ecosystems. Additionally, adding microplastics to the oceans and waterways are detrimental to oceanlife.

Systems Condition 4

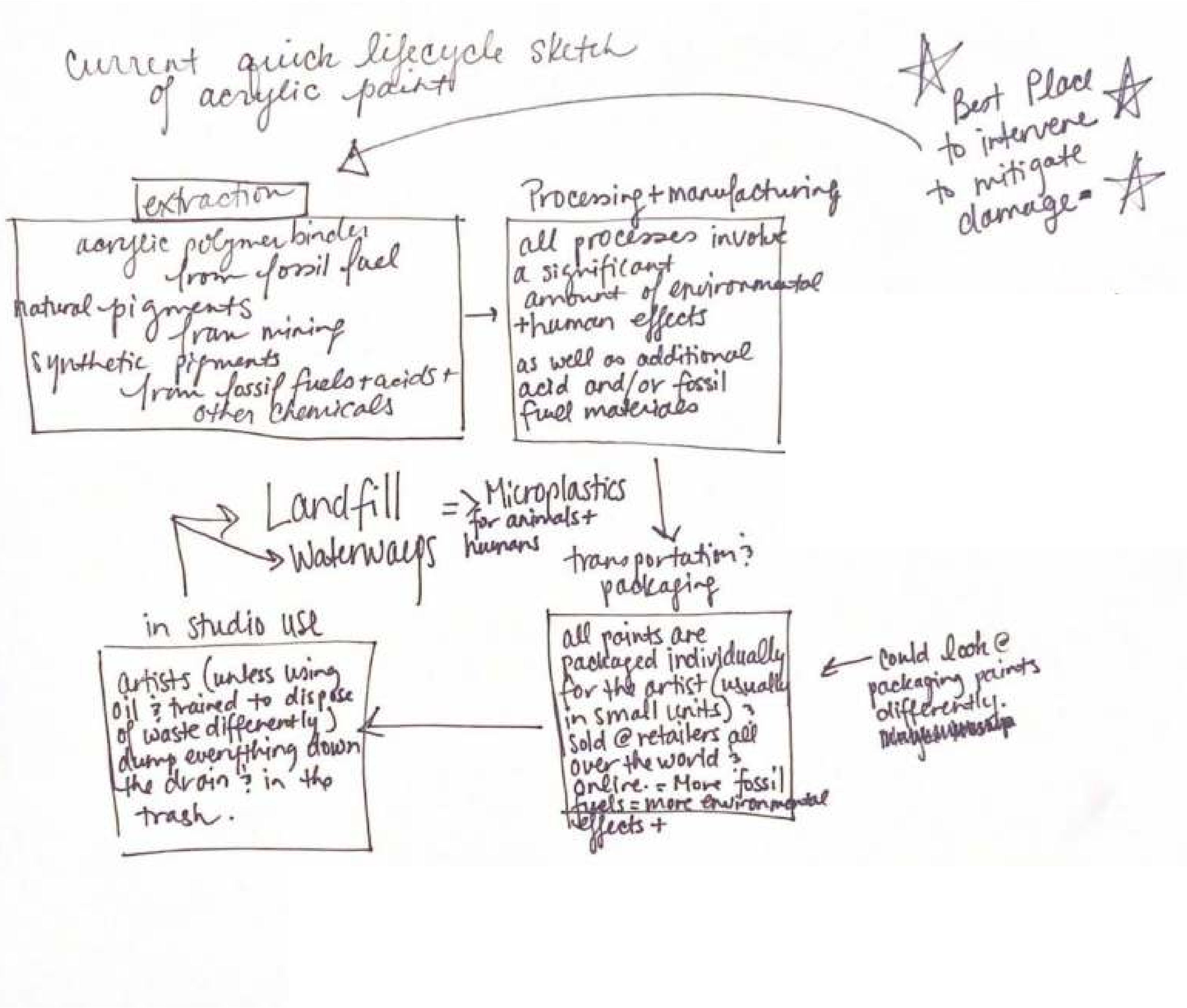
“In a sustainable society resources are used fairly and efficiently in order to meet basic human needs globally.”

Refineries contribute to racial and socioeconomic health disparities due to where they are located. Additionally, mining companies often contribute to exploiting communities who don’t have the means or the power to fight them and contribute to the socioeconomic disparities.

Thinking through where the best place to intervene would be in this particular life cycle, the biggest impact in the life cycle diagram seemed to come from the materials chosen at the extraction point in the cycle which influences the processing and manufacturing stage. If materials were chosen that were not extracted from crude oil, they wouldn't have to be processed in a refinery.

Following up on brainstorming idea(s):

- Making the environment a stakeholder in the art making process & making it a priority.
- Consider educational components: What does water-based paint mean? What are the impacts of an acrylic paint?



INITIAL IDEAS

Source locally for Pigments

Where could an artist source color instead of going to the art store?

- Botanical (flowers, plants, bark, roots, etc.)
- Agricultural Waste (the kitchen!)
- Technical Nutrients (such as copper wire)
  - Check Red Lists before proceeding!
- Biological (trickier)
- Earth

Following up on brainstorming idea(s):
- Honorable Harvesting/Ethical Foraging.
- Explore the concept of land art within the context of this project. Does the messaging and values of sustainable art outweigh the convenience of acrylic paint?
- Connecting/Respecting nature.
- Ink & Pigment making from Botanical, Agricultural Waste and/or Earth (natural materials & only from abundant and renewable sources). Also consider invasive species.

What did artists use prior to the Industrial Revolution to create paint?

- Researching historical texts for recipes.

- Pigments from the Romans through the 18th century were laked on calcium carbonate (chalk) or aluminum potassium sulfate (alum). Alum are essentially pickling salts. Are there pickling salts that can be composted? Calcium carbonate can also be made from eggshells?

- Heating Kaolin clay and indigo gets you a mayan blue.

- Once the pigments are made, it’s a matter of finding the kind of art material one would like to make such as oil paints, tempera paints, screen printing inks, etc.. The goal is to find water-based media and finding the materials that are compostable for them.

Following up on brainstorming idea(s):
- Get knowledge from teachers of ink & pigment making, source historical alchemy books & recipes, and research into other cultures who made their own paints for various hand making skills.

CONCEPT MOVING FORWARD

This project aims to explore sustainable alternatives to artist materials by utilizing locally sourced earth, plant, and waste stream materials in a local radius.

The primary objective is to develop a process of making one's own paints that can be easily executed by any artist in their kitchen, without the need for a full chemistry lab and at an affordable cost.

In order to meet the project's time constraints, the focus will primarily be on developing water-based media recipes. The research will involve conducting a life cycle assessment (LCA) analysis to compare the environmental impacts of conventional materials with those of the newly developed materials in this project.

Source: Canva

05

MATERIALS EXPLORATION

The following pages explores materials used in acrylic paintings using the Sustainable Minds software.

The baseline is for 10 acrylic paintings, size 16x20 inches.

ALTERNATE CONCEPTS EXPLORED:
1) Locally Manufactured (if all manufacturing was moved to Minneapolis - local to this author)

2) Alternate Substrate - Wood

3) Foraged pigments using commercially made acrylic binders on commercial made canvases

4) Handmade recycled paper with locally foraged diy pigments for inks, watercolor or tempera paints


Source: Canva

WHAT IS IN ACRYLIC PAINTS?


Source: Canva

Discovering precise formulas for acrylic paints presented a significant challenge. The manufacturers of artist paints had inadequate safety data sheets, rendering them unhelpful. Fortunately, researching household acrylic paints provided more valuable information, serving as the primary source for material investigation.

Research into painting restoration proved the most enlightening. An article published by the Tate Museum in London summed it up this frustrating challenge the best. They found three fundamental problems with conservation of acrylic paintings. “The second was the complete lack of knowledge about acrylic emulsion systems, especially the complexity and constant changes to the formulas, with insufficient information coming from the manufacturers of both raw materials and artists’ paints.” Artists don’t know what’s in them, manufacturers aren’t sharing what’s in them (and also may not know what’s in them or what exactly their supply chain is) and it’s constantly changing.

For the following materials research, acrylic varnishes and acrylic binders were chosen, but it should be noted that there are many other materials such as plasticizers, stabilizers, and other additives that are not accounted for since they are not available in the Sustainable Minds software. They are noted in the Lifecycle diagram.

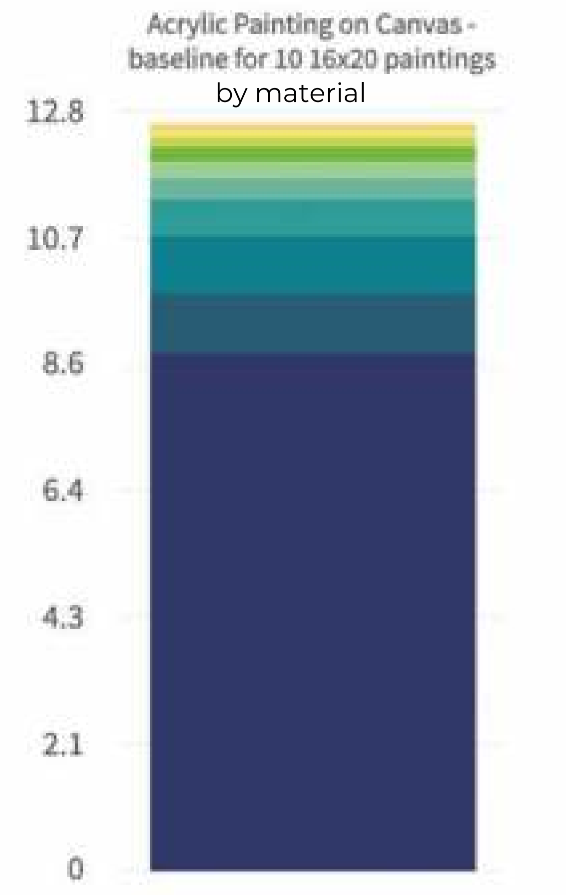
REFERENCE

Acrylic Painting using commercial acrylic paint & canvases manufactured overseas - 10 paintings, size 16x20 inches

A 2011 study from the US Census bureau estimated approximately 200,000 fine artists in the US which included art directors; craft artists; fine artists include: painters, sculptors, and illustrators; multimedia artists; animators.

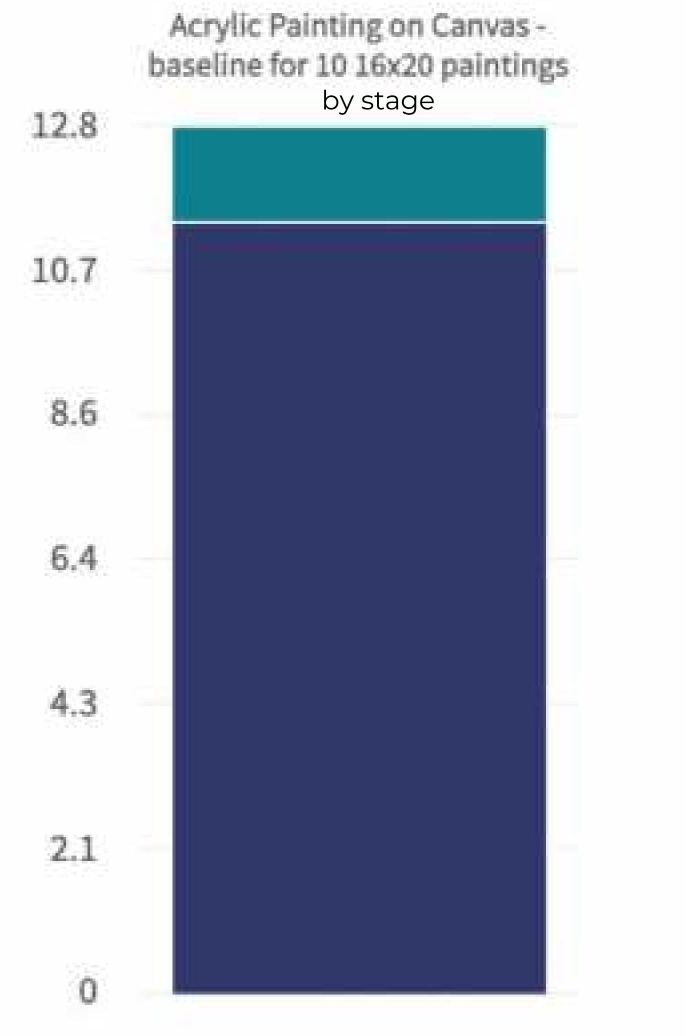
If we assumed conservatively that 10% of the 200,000 full-time artists used acrylic paint and in one year produced 20 paintings, that is the equivalent of **1,146,403 lbs** of CO2 emissions emitted every year just in the US by painters using acrylic paint.

Keeping in mind that this is only based on artists who reported themselves as full time artists to the census bureau. This does not include those who are part-time or hobbyists, which this author assumes is more than 4x this number, in addition to the schools and youth art programs that use acrylic paints.



Total = 13 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118



Total = 13 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Manufacturing	11.4
End of life	0.0233
Transportation	1.38
Use	3.29×10^{-3}

05

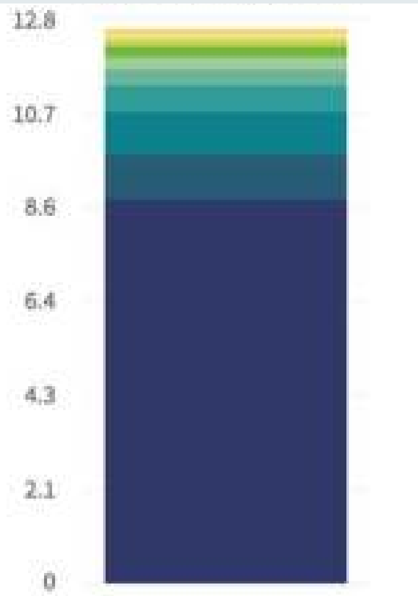
Materials Exploration/Concept 1

LOCAL MANUFACTURING

Acrylic Painting using commercial acrylic paint & canvases manufactured locally in Minneapolis.

+5.5% Improvement

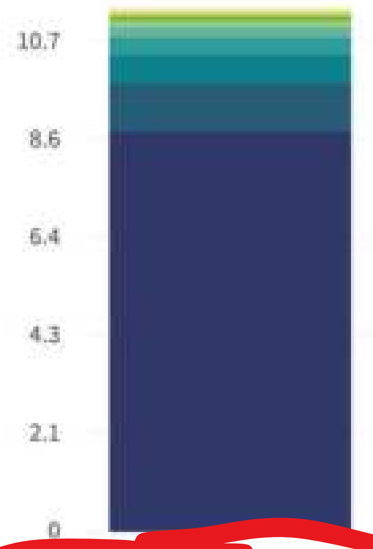
Reference by material



Total = 13 CO_2 eq. kg/func unit

Input	CO_2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118

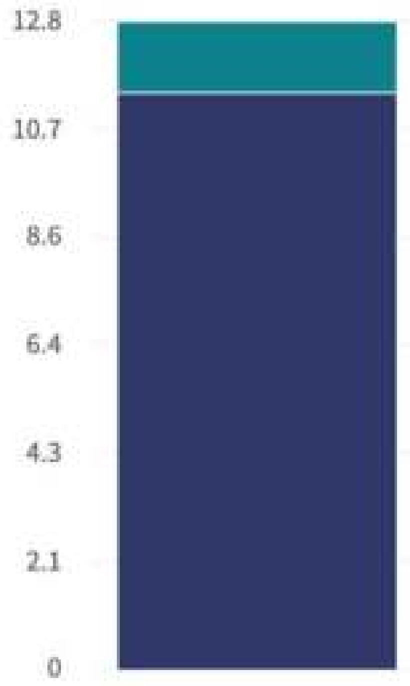
Locally Made Concept by material



Total = 11 CO_2 eq. kg/func unit

Input	CO_2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Material - Acrylic varnish, 87.5% in H2O	0.236
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118
Material - Cadmium, primary	0.0668
Process - : Wire drawing, steel	0.0435
Process - : Wood, planing	0.0277

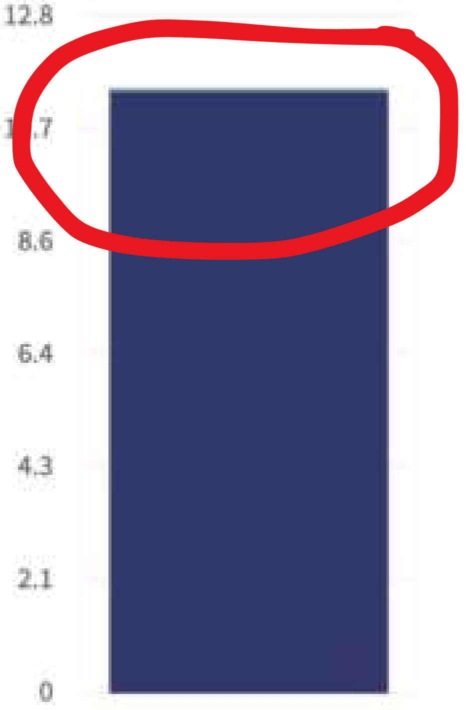
Reference by stage



Total = 13 CO_2 eq. kg/func unit

Lifecycle stage	CO_2 eq. kg/func unit
Manufacturing	11.4
End of life	0.0233
Transportation	1.38
Use	3.29×10^{-3}

Locally Made Concept by stage



Total = 11 CO_2 eq. kg/func unit

Lifecycle stage	CO_2 eq. kg/func unit
Manufacturing	11.4
End of life	0.0233
Use	3.29x10⁻³

EcoDesign Strategy Used
Design for Reduced Distribution Impacts: Use local production and assembly

This concept explores the idea of the items being locally made (in Minneapolis) instead of made in China; therefore eliminating the need for ocean freight or long distance large haul trucks.

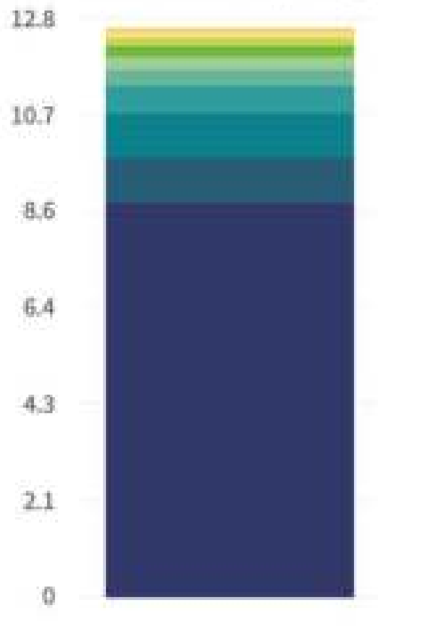
This concept assumes all ingredients are not changed, only the location of where the paint and canvases are made is changed.

WOODEN SUBSTRATE

Acrylic Painting using commercial acrylic paint & wooden substrate manufactured overseas.

+88%
Improvement

Reference by material



Total = 13 CO_2 eq. kg/func unit

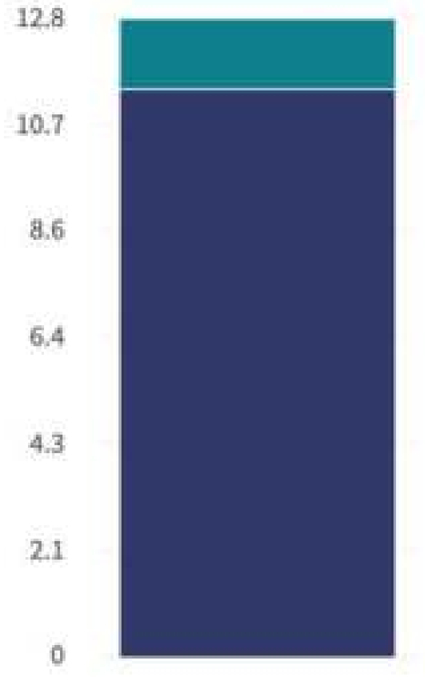
	Input	CO2 eq. kg/func unit
	Material - Woven cotton fabric	8.75
	Material - Titanium dioxide, production mix, inorganic	1.04
	Transportation - Truck, 20-28t	0.944
	Material - Stainless steel, austenitic	0.621
	Material - Acrylic binder, 34% in H2O	0.363
	Transportation - Truck, 20-28t	0.283
	Material - Acrylic varnish, 87.5% in H2O	0.236
	Transportation - Freighter, oceanic	0.157
	Material - Carbon black	0.137
	Material - Acrylic varnish, 87.5% in H2O	0.118

Wooden Substrate Concept by material

Total = 2.8 CO_2 eq. kg/func unit

		unc unit
	Transportation - Truck, 20-28t	1.05
	Material - Titanium dioxide, production mix, inorganic	0.522
	Material - Acrylic binder, 34% in H2O	0.363
	Transportation - Truck, 20-28t	0.314
	Transportation - Freighter, oceanic	0.175
	Material - Carbon black	0.137
	Material - Acrylic varnish, 87.5% in H2O	0.118
	Material - Beech timber	0.0976
	Material - Cadmium, primary	0.0668
	EOL - : Landfill, polyurethane	5.63x10⁻³

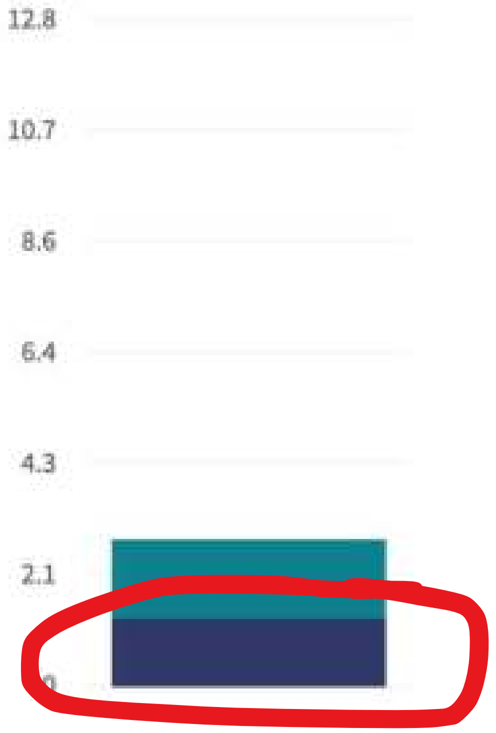
Reference by stage



Total = 13 CO_2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Manufacturing	11.4
	End of life	0.0233
	Transportation	1.38
	Use	3.29×10^{-3}

Wooden Substrate Concept by material



Total = 2.8 CO_2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Manufacturing	1.30
	End of life	6.26x10⁻³
	Transportation	1.54
	Use	3.29x10⁻³

EcoDesign Strategy Used
Design for Reduced Material Impacts: Minimize Quantity of Materials

This concept explores using wood as a substrate instead of the more common canvas. Therefore, transportation was left the same as the baseline and assumes all materials would still be made in China and shipped to the US.

This method eliminated staples, canvas, stretcher bars, and 4oz of titanium oxide as well as 4 oz of acrylic varnish both of which are combined to make gesso to coat a canvas but which would not be needed (although could still be used depending on the artist preference) in the case of a wood panel.

This change of substrate minimized materials and significantly lowered impacts.

To further reduce impacts, looking for local sources for FSC offcuts from local business or even handmade recycled papers would be worth exploring.

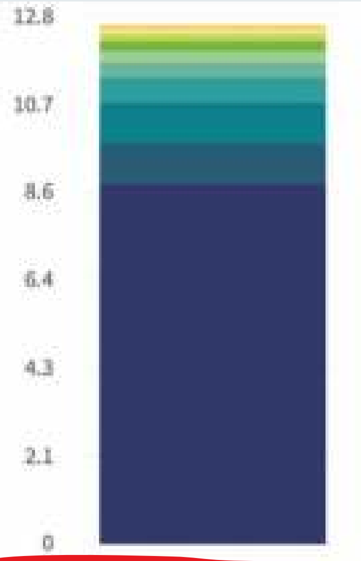
05 Materials Exploration/Concept 3

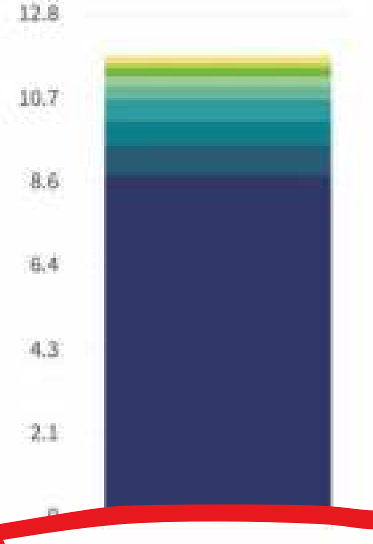
FORAGED PIGMENTS

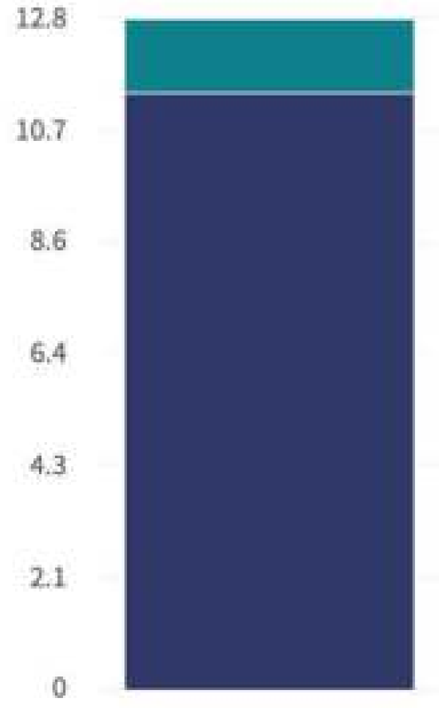
with commercial acrylic binders on commercial canvases manufactured overseas.

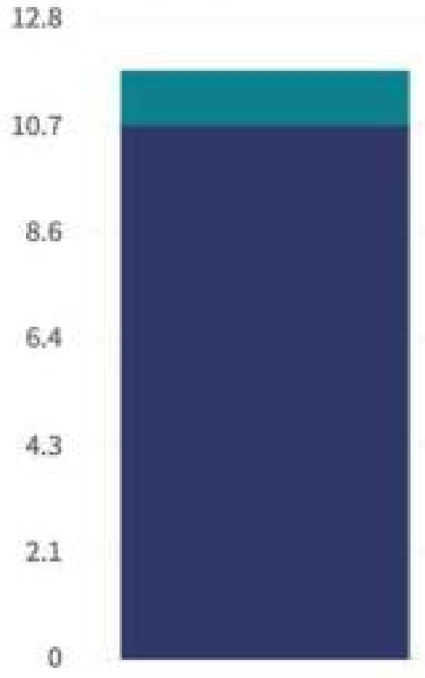
+3.8%
Improvement

Reference by material	Foraged Concept by material	Reference by stage	Foraged Concept by material









Total = 13 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118

Total = 12 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Transportation - Truck, 20-28t	0.766
Material - Stainless steel, austenitic	0.621
Material - Titanium dioxide, production mix, inorganic	0.522
Material - Acrylic binder, 34% in H2O	0.363
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Truck, 20-28t	0.230
Transportation - Freighter, oceanic	0.128
Material - Acrylic varnish, 87.5% in H2O	0.118
Process - : Wire drawing, steel	0.0435

Total = 13 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Manufacturing	11.4
End of life	0.0233
Transportation	1.38
Use	3.29×10^{-3}

Total = 12 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Manufacturing	10.7
End of life	0.0227
Transportation	1.12
Use	3.29x10⁻³

EcoDesign Strategy Used
Design for Reduced Material Impacts:
Use renewable resources

This concept explores foraging for pigments, but still using a commercially made binder to create the paints as well as a commercially available canvas.

This seems to be the most common starting place for artists who are new to foraging for pigments. For example, artist may use dirt, charcoal, etc... as a colorant and use an acrylic binder to bind the materials to the canvas.

Titanium Dioxide is still present because it is used by the canvas manufacturers to pre-prime the commercially bought canvases.

The performance improvement is significantly lower than expected. The artists using this strategy are not nearly making the impact they likely think they are.

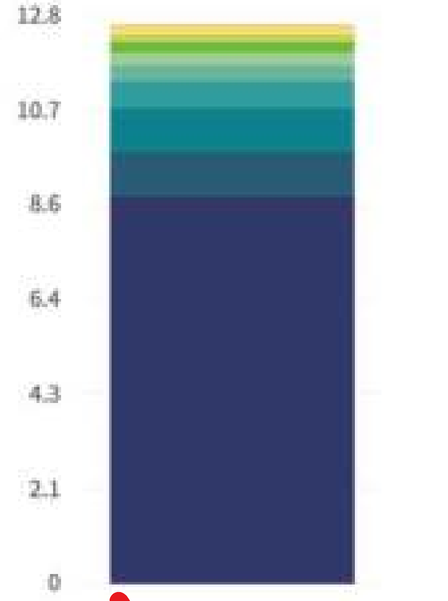
05 Materials Exploration/Concept 4

HANDMADE

Handmade recycled paper with foraged inks or watercolors made locally

+100%
Improvement

Reference by material



Total = 13 CO2 eq. kg/func unit

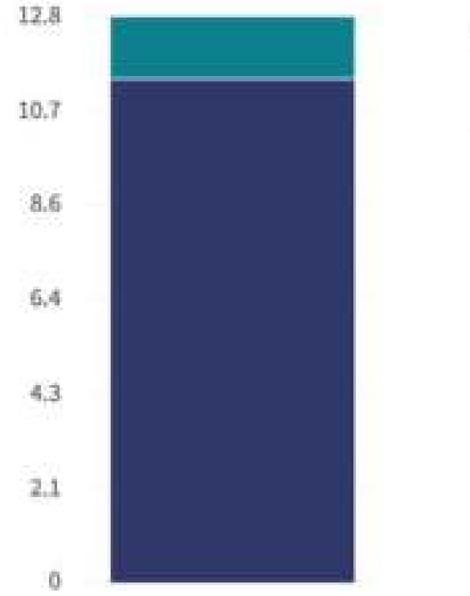
	Input	CO2 eq. kg/func unit
	Material - Woven cotton fabric	8.75
	Material - Titanium dioxide, production mix, inorganic	1.04
	Transportation - Truck, 20-28t	0.944
	Material - Stainless steel, austenitic	0.621
	Material - Acrylic binder, 34% in H2O	0.363
	Transportation - Truck, 20-28t	0.283
	Material - Acrylic varnish, 87.5% in H2O	0.236
	Transportation - Freighter, oceanic	0.157
	Material - Carbon black	0.137
	Material - Acrylic varnish, 87.5% in H2O	0.118

Handmade Concept by material

Total = 3.3x10-3 CO2 eq. kg/func unit

	Input	CO2 eq. kg/func unit
	Use - Tap water, at user	3.29x10⁻³
	Transportation - Van, <3.5t	0

Reference by stage



Total = 13 CO2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Manufacturing	11.4
	End of life	0.0233
	Transportation	1.38
	Use	3.29×10^{-3}

Handmade Concept by stage

Total = 3.3x10-3 CO2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Transportation	0
	Use	3.29x10⁻³

EcoDesign Strategy Used
Design for:

- **Optimized manufacturing**
- **Reduced Distribution Impacts**
- **Reduced Material Impacts**
- **Optimized End-of Life**

This concept explores creating a substrate locally from recycled paper. The only input needed would be water, if the paper is sundried.

Pigments can be locally sourced from kitchen waste, botanicals or even earth. Instead of using an acrylic binder, locally available ingredients such as eggs and honey can be used.

This eliminates the acrylic & varnishes binders, the metal based pigments, as well as the components needed to support a canvas substrate. Additionally, because this can all be created locally, there is no additional transportation. Some transportation was included, with the most efficient vehicle available in Sustainable Minds being a van. Water is still accounted for which is needed to create the paper and the pigments, but less is needed to clean materials since the acrylic binders and varnishes are no longer present.

Takeaways

- Most artists starting to play with more natural materials in their art will begin with mixing earth materials with commercially available binders. These are usually still used on a primed canvas. This concept was explored in Concept 3 and it was surprising to see that this type of shift in paint making only resulted in a +3.8% change in sustainability from the baseline.

Most surprising

- Concept 2 explored changing nothing other than the substrate from a traditional canvas to a wood substrate and this resulted in a +88% change from the baseline. This still assumes the artist primes the wood with a clear primer and uses commercially available acrylic paints.

Most efficient

- Concept 4 assumed the substrate was recycled instead of new, therefore eliminating the manufacturing of the material in addition to the transportation from China (but adding possible local transportation to source the recycled material). Additionally, it eliminated all acrylic polymers and mined pigments in exchange for materials that could be foraged such as flowers, earth or kitchen waste which resulted in a +100% change.

Most effective

06

PROJECT DEVELOPMENT:

PLACE BASED PAINT MAKING

PAINT TYPES

What water based mediums can be created without the use of acrylic polymers?

★ **Inks**

Inks can be made simply with water and a flower or plant. Some recipes add salt or a little vinegar to coax out a color. Thickeners can be added, but aren't necessary.

★ **Watercolors**

Illuminators of the past made watercolors with pigments, gum arabic and honey.

★ **Tempera & Glair**

Tempera paints, popular in the Middle Ages & Early Renaissance, can be made with egg yolks and water.

★ = chosen options for this project

Oils

- Oil paints are simply pigment plus a drying oil like walnut, safflower or linseed. However, the issue with using oil paints lies in the disposal of the oil soak rags which can cause fires, in addition to the solvents whose VOC emissions (according to the EPA) have human health effects such as
- Eye, nose and throat irritation
- Headaches, loss of coordination and nausea
- Damage to liver, kidney and central nervous system
- Some are suspected or known to cause cancer in humans.

Inks can be made directly from the base materials.

Watercolors and Tempera need to be made using pigments, so pigments will be need to be created first.

MATERIALS CHOSEN

- Botanical
  - Decided to make a connection with a local dye expert who owns an organic floral dye garden. Their expertise on the flora, the colors they give, and the knowledge that no pesticides were used on the farm made it a perfect collaboration for this project. And they were within the given radius.
- Agricultural Waste (the kitchen! - eggs and onion skins)
  - Eggs were washed with water and kept in a bowl on the counter, and a separate bowl was kept for onion skins until there was enough for this project. Some eggs/eggshells were donated from neighbors who raise chickens in their backyards.
- Earth (not specified, just local to my area)
  - Foraged on walks in our area.

Design strategies explored: Source Responsibly & Renew Resources

- Source sustainably-managed renewable resources
- Source local materials
- Use annually-renewable or rapidly renewable materials
- Practice the Honorable Harvest

DESIGN FOR SUSTAINABILITY

An overview of strategies employed in the project

Design for Reduction - Substitution
Changing binders so that acrylic polymer emulsions were no longer an option

Design for Reduction - Localization
Encouraging artists/makers to use resources as local as possible to them as much as possible in the creation of their own work not only challenges the artist to think more creatively, but it also creates a sense of place (stories) in their work, builds collaborations within their community, and hopefully bolsters their local economy.

Deep Ecology
The intrinsic value of non-human life as a priority = only take what you absolutely need.

Design for Composting
The hope was to be able to compost everything, but some materials are able to be composted in comparison to nothing being able to be composted for acrylic paint.

Biomimicry
Design optimizes rather than maximizes
Design uses benign manufacturing
Design leverages its interdependence in the system
Design is locally attuned and responsive

The Natural Step
Considers all 4 systems conditions by not taking more than is needed, not adding substances into the atmosphere that cannot be broken down, not using (or using very little) coal for energy, and having a transparent supply chain where equitable work is considered and local artisans are paid.

Sourcing Responsibly
source local materials. Source from vendors who meet or exceed fair labor & trade practices.

Three Pillars of Sustainability
When creating the recipes, the whole system was considered and was looked at as a holistic approach for an artist.

DESIGN FOR SUSTAINABILITY

An overview of strategies employed in the project, cont...

Hannover Principles

- Insist on the right of humanity and nature to co-exist.
- Recognize the interdependence between the natural world and the human world.
- Create safe objects of long-term value without burdening future generations.
- Rely on natural energy flows
- Eliminate the concept of waste - this one still needs more research

Design for Carbon-Neutral Renewable Energy

Creating paints at home with these recipes uses climate neutral sources and reduces demand on energy.

Design to Encourage Low Consumption Behavior

The nature of these recipes is that most paints should be made as they need to be used. Gone will be the days of buying large amounts of paints needlessly and storing them on a shelf for the day that they might be needed. Additionally, working with the seasons means there are certain materials that are only available for a short window. If an artist is working with kitchen waste, only certain materials will be available.

Okala Ecodesign Strategies Used

- Optimized manufacturing
- Reduced Distribution Impacts
  - Use local production and assembly
- Reduced Material Impacts
  - Use renewable resources
  - Minimize Quantity of Materials
- Optimized End-of Life

The Precautionary Principle

Titanium Dioxide and the accumulation of microplastics are both topics that are still lacking in regulation in the United States. For this project, both were eliminated from use entirely.

CAUSE NO HARM, CREATE NO NEW PROBLEMS

Precautionary Principle

"This principle asks businesses to use foresight in the development of new products and processes and, if these are deemed potentially dangerous to society, to refrain from further action." Andres R. Edwards

The research by Earth Action illustrating the problem with microplastics in the oceans and waterways from acrylic based paints is new as of 2019. An article from Altasea.org estimated as of 2022, there are between 50 and 75 trillion microplastics in the ocean. However, it is very difficult to measure the effects of microplastics in something as fluid and vast as the oceans and waterways.

Beyond that, the effects of the microplastics, as has already been studied, goes beyond just the fish. It could take decades to get accurate measurements of the effects of microplastics on humans, the environment and other living organisms. By the time we have the research it might be impossible to reverse any of these effects.

Implementing the Precautionary Principle and eliminating the potential bad actor, acrylic polymers, all together out of the artist studio even without explicit evidence and/or government regulation allows us to take action now.

It is worth noting that the EU has already taken action on Titanium Dioxide in food and has deemed it a carcinogen and banned it in food. Other governments are not yet following suit.

CREATE "GREEN" JOBS

"Green" jobs, according to the United Nations Environment Program, refers to work "that contribute(s) substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution."

Design Strategy Explored: Buy locally-made, artisan-made material

Materials purchased for this project:

- Honey purchased from MCAD student bee club.
- Eggs purchased from the local community owned co-op who do great things to support our community. The eggs they sell are from a local farm. Another option is purchasing eggs from a neighbor who sells eggs from their backyard. An option for scaling would be partnership with a local bakery (who gets eggs locally).
- Flowers for this project where purchased to a local textile artist who is growing her own flower farm as part of her growth as a natural dyer.

Further options considered but not implemented for this project would be looking for alternate substrates. As shown in the LCA research, considering wooden or paper substrates that are locally sourced would create a significantly lower impact than purchasing ready-made canvas substrates from the art store. Consider finding a furniture maker, or builder who works with wood certified by the Forest Stewardship Council and getting off-cuts for substrates. Or find a local artisan who makes their own paper from recycled natural cotton fibers or recycled paper.

Beyond buying from local artisans, there is the possibility of paint making becoming a local artisan made job itself for artists. Once they start making their own paints, they have the opportunity to create a new "green" job out of it themselves based on the unique natural make-up of their own area.

Design strategy explored: Design for connection with nature, Deep Deep Ecology Principles

When relying on the local environment as inspiration for artistic materials, one becomes increasingly attuned to their surroundings. What is currently in season? Which plants are blooming? Where can oak trees and acorns be found nearby? Are coneflowers native to my area?

Once the fundamentals of creating ink or making a lake pigment are mastered, exploration and experimentation becomes more exhilarating. Questions like, "What colors can be extracted from this specific plant?" arise more frequently. Spending more time outdoors and maintaining a journal to track seasonal changes become essential.

This information can serve as a valuable reference for future sourcing, such as noting the best time and location to obtain sumac abundantly. Natalie Stopko stated that a plant contains up to 20 different colorant molecules which fluctuate over the seasons. Depending on when the plant is foraged, the health of the soil, the amount of rain that year, the amount of sun the plant gets, etc... the paint created could be up to 20 different colors! This is why paint makers and natural dyers will often keep very detailed records of the plants they use, and also why it can be very difficult to replicate colors.

The more time spent outside, the stronger the connection to nature becomes. Fritjof Capra, a renowned deep ecologist, believed it was imperative to understand the patterns and processes by which nature sustains life. By spending time outdoors through the seasons one begins to notice these patterns and relationships within the bigger system.

FORAGING FLOWERS

Salt of the North Farm, Northfield MN

Photo Credit: Salt of the North

- Only take what you need from an area that is plentiful. It must have the ability to renew itself.
- Look and research before you take anything so there is nothing wasted.
- Give in return: How can everyone thrive?

Salt of the North Farm is a dye flower farm currently researching more sustainable and regenerative farming efforts. They offer a U-Pick evening on the farm for the community to pick flowers that are currently blooming from their variety of dye flowers. Pick off the heads of the flowers (which is needed to promote continued growth of the plant) and pay per gram on a sliding scale basis.

All were planted because of their proven dyeing ability (the farmer is also an avid natural dyer) so it was certain they would give some good ink colors.

When looking for local plants a plant identifier app works well when paired with research on whether or not the plant was historically (or is currently) used in dyeing. This will often tell if it is a good plant for making ink. Be sure to double check that the plant is not poisonous! When in doubt, leave it alone.

A tip from Salt of the North, freeze the foraged flowers until it's time to use them.

FORAGING EARTH PIGMENTS

Pick up bits of earth and test the texture. Look for clays, or stones that are somewhat soft to the touch.

To test a stone, scratch the surface of another stone and see if it leaves a streak of color easily. If so, it's likely a good candidate for making a pigment.

Harder stones could work but will require a lot of muscle and machinery to break it down, so it might be best to leave it where it is.

- Be mindful of the cultural practices that relate to the locality
- Learn more: the history of the place, geology, typography, ecological systems, interspecies communities
- Think about the art ecosystem your pigment will live in. How will this lovely pigment "live" with the other art materials in the artwork?

For this project stones were foraged from an area around Coldwater Springs by the Mississippi.

RECIPES

Making Ink from Plants

Making Egg Shell Pigment

Making Tempera & Glair From Lake Pigments Created with Onion Skins

Making Watercolor & Gouache with Earth Pigments

ABOUT THE RECIPES

The recipes in the following pages were results from hours of classes and readings from various teachers with expertise in these particular recipes.

An effort was made to reduce materials as much as possible, and use materials like egg shells whenever possible to replace commercially purchased calcium carbonate or chalk. Heat was used minimally, but was noted when there would be an alternative.

Since these recipes were meant for artists to just get a feel for the recipe, the amounts were kept small in order to minimize any waste, although they are scalable.

All teachers are noted for each recipe.

Takeaways on the processes are at the end of each recipe section.

INKS

INKS

Recipe adapted from Jason Logan and Tortolia Inventiva

Materials:

- 1 cup flowers (this is a double black hollyhock)
- 2 cups distilled water
- 1 pan (must not have any rust)
- 1 wooden spoon

1 Extract colorant
Over low heat, cook flowers in water until desired color is created, approximately 1-2 hours.
Do not let water boil.
Be sure not to let water evaporate. If need be, add a bit more water. Some flowers will create a deep color, some will be lighter.

OR- Place dried flowers in a jar filled to the top, then add distilled water to the top. Close tightly and store somewhere dark until color is extracted. This could take weeks.

2. Filter
When the desired color is reached, strain the ink through a very fine coffee filter into a storage jar. It may take some time to filter.

It is best to store in a refrigerator. Some recipes call for adding a clove bud or some wintergreen oil as a preservative.

3. Compost
The flowers can be place in the compost.

The coffee filter can be dried and used as shifu paper or a color sample.

Double Black Hollyhock

MODIFYING INK

The colors of the ink can be modified by changing the pH levels and using a few household ingredients. Some will be very little change, and some might be quite significant.

However, please note that adding these modifiers will likely change the ability of the ink to be composted.

Here are the modifiers used to change the colors of the Black Hollyhock ink:

- Cream of Tartar
- Citric Acid (or Lemon)
- Pure Soda Ash (Otherwise known as Washing Soap)
- Baking Powder
- Baking Soda
- Calcium Carbonate (used in lake pigment making)
- Alum (also known as pickling salts - a mordant used in dyeing. These are food grade)

Be sure to keep detailed records for reference.

This is a quick art piece created using only Black Hollyhock ink with 3 different modifiers.

It's important to talk about the fact that these inks are not lightfast. It's best to keep them out of light as much as possible.

Adding alum to the ink will make the color more stable (not completely stable), but remember that it will also likely change the original color that was created in some way depending on it's original pH level.


June 2023


December 2023

Other botanicals explored for ink

Dyers Chamomille

Dried Hibiscus

Coreopsis

French Marigold

Viola

Black Eyed Susan

INKS

Takeaways

Meets the artists requirements of:

- less intimidating than oils
- affordable
- easily accessible
- can clean with water
- less smell than oil painting

Does not meet:

- opaqueness

Findings:

- The plants are renewable if sourced from a renewable source and managed responsibly.
- There is the possibility of no additives being used that could hinder the artwork from being composted thus creating the possibility of artwork created for compost or a cradle to cradle product.
- The creation process, can be made with sunlight instead of over heat reducing impact further with a biomimetic principle of using only sunlight.
- If the artisan creates their own dye flower garden using native plants, using systems thinking and regenerative ecology they could also contribute to regenerating the native floral and fauna in their area depending on the needs of their local area (reducing run off, etc.)
- Inks could also be made from kitchen waste creating another opportunity for material use and waste reduction.
- An artisan could easily make a small business stream of making local inks, bolstering the local economy and supporting artists who want to use sustainable materials but who don't want to make them creating more local artisan jobs, sharing knowledge and building a more sustainable community ecosystem.
- This can be an easy LCA analysis with knowing where all the materials come from, providing a transparent supply chain.
- These inks are not stable. This would mean a new perspective on behalf of the artist and the "client" as to what to expect out of the artwork.

EGG SHELL PIGMENT

EGG SHELL PIGMENT

This recipe from Natalie Stopka

Materials:
- 3-4 Egg Shells
- 2 jars
- Mortar and pestle
- glass palette and muller
- distilled water
- vinegar
- paper coffee filter
- something in which to store dry pigment

1 Clean egg shells with water

2. Add egg shells to a jar with 1 part water 1 part vinegar solution and let sit for 10-30 minutes. This solution will begin to dissolve the shells so do not leave them unattended for too long.

3. Rinse in another jar of distilled water to rinse off the vinegar solution.
Pull the membranes out of the egg shells (these can be put in the compost.

4. Crush and grind shells with mortar and pestle as fine as possible.

5. Place a tablespoon of the crushed shells on the glass palette and add 1/2 tablespoon of water. When it's ground as fine as possible, continue with the rest of the egg shells.

7. The watery pigment can be placed in a paper coffee filter and left to dry.

The pigment can be stored at this dry consistency. When it’s time to use the pigment, it would need to be ground either in the mortar and pestle or dry on the palette with the muller to get it into a fine powder consistency again.

This egg pigment works well with most water based media but tends to go transparent in oil media.

This is actually calcium carbonate and can be used to make lake pigments to replace commercial calcium carbonate, and can also be used in gouache as a white filler.

EGG SHELL PIGMENTS

Takeaways

Meets the artists requirements of:

- affordable
- easily accessible
- can clean with water
- less smell than oil painting
- opaqueness

Does not meet:

- less intimidating than oils

Although the steps in this recipe are not complicated once practiced, it does seem intimidating.

Findings:

- There is a simpler way of processing egg shells of leaving them in citric acid and letting the acid do the work of breaking down the shells. However, this also adds acid to the process which would change the end of life. The current process using only water makes all waste completely compostable.
- This example of processing egg shells is an example of biomimicry (and bio utilization) using only water to make something new and there is no waste because it can be food for something else (the garden in this case).
- Egg shells are a calcium carbonate. Other options would be oyster shells (and other shells and coral), marble, limestone.
- Consider again the impact the fossil fuel industry has. “Acid rain, produced when emissions from fuel burning combine with water in the atmosphere, dissolves limestone and marble structures and artwork and acidifies rivers, lakes and ocean water. In turn, this causes aquatic shells to weaken and begin to dissolve, with major ramifications upon ecosystems.”

LAKE PIGMENT, GLAIR & TEMPERA

Tempera and glair are water based paints that are not rewettable.

In order to create these paints, pigments must first be created.

What are lake pigments? They are pigments created by utilizing an inert binder to precipitate a dye. More information is linked in Appendix C.

This recipe will give steps to create pigments through the laking process using kitchen waste, in this case it is onion skins.

Then it will be followed with using the pigments created to make tempera and glair. It should be noted that the pigments created in this recipe could also be used to create watercolors and gouache, just like the earth pigments created in the next recipe could be used to make tempera and glair.

This technique can be used with any plant from which dye can be extracted. Artisans have used avocado pits, dye flowers, red cabbage, nettles, black walnuts. Do some research into what plants can be used for dyeing as a place to start. Then consider what grows locally.

Color fastness varies depending on the material used.

This recipe uses every part of an egg.

The shell is used in the lake pigment process.

The egg white is used to make glair paint.

The yolk is used to make tempera paint.

LAKE PIGMENTS WITH ONION SKINS

Adapted from Natalie Stopka, Anabel Torres, and Lucy Mayes.

Materials [2]

- Jars/Beakers (please clean and sterilize in boiling water)
- Measuring Spoons for stirring and measuring
- Funnel - optional
- Coffee filters
- Pestle and mortar
- 3g Onion Skins
- Distilled Water
- 6g Alum (aluminium sulphate) - food grade if possible
- 3g Calcium Carbonate (or processed egg shells)
- Mask - recommended

Consider purchasing as much as possible second hand.
Once you've used any equipment for dyeing, don't use it in the kitchen again.

1. Add 3g onion skins (yellow or purple) to 200ml of distilled water.
Let soak overnight so dye softens and color is more intense.

OR - warm over heat for 1 hour (but this requires additional energy use).

2. Filter through a coffee filter into another vessel.

3. Once it is completely filtered, transfer to a beaker so that it can be heated on low heat. Or put jar in a pan of water to heat.

4. Add 6g aluminum sulfate to hot onion skin solution. Alum will not completely dilute if the solution is not hot. Stir and wait until completely diluted. If not completely diluted the pigment could have too many crystals.

5. Once the pigment is completely diluted, place jar or beaker in a baking pan (or something similar) with sides. Once the calcium carbonate is added it will effervesce and possibly bubble over and make a mess. This will help contain it.

6. Add 3g calcium carbonate quickly and all at once.
Stir with a stir stick. Stirring the bubbles helps keep it from bubbling over. Let settle.

7.Filter the fluid through a coffee filter. Filtering may take an hour or two.

8. Wash the colorant, remove all the colorant that could not bind to the alum or the calcium carbonate, and all the alum and calcium carbonate that could not bind to the colorant.

Take the coffee filter as-is and dunk it in a fresh vessel of distilled water, releasing all pigment into the water & pulling the now clean filter back out.

Decant and filter through a fresh filter. Repeat once more.

At this paste-like stage (after it has filtered but before it is dry), it already has the exact same properties as the dry pigment. You CAN leave it like this and use it! by directly mixing it with a water based binder à la minute. Store in the refrigerator with a couple drops of antifungal oil (like clove oil or wintergreen oil). However, it will not last as long as a dry pigment.

9. Put it somewhere to dry that is ventilated and out of direct sunlight. After a day or so you will get a dry, powdery-like substance. OR - to speed the drying it can be dried in the oven at the lowest temperature but this requires additional energy use.

10. Grind in a mortar and pestle to a powder consistency. The more fine the powder, the easier it will be to work with when making paints. For glair and tempera specifically, the pigments will need to be very fine.

Store away from humidity and direct sunlight since these pigments are light sensitive. *Photo was taken before the pigment was ground finely*.

GLAIR

Adapted from Caroline Ross, Scriptorium Yayyan and Robert Massey[2]

Note: Glair and Tempera paints should not be stored. Only make as much as is needed to work for the day. Can be used on many substrates.

Materials:

- 1 egg white
- a fork or a beater
- a mixing bowl
- a glass palette and muller for mulling paint
- distilled water
- palette knife
- something to put the paint into when mixed (a small vessel)

1 In a mixing bowl, add one egg white.

2. Beat until egg white forms stiff peaks.

3. Tilt bowl to side and store like this for 1-5 hours. A liquid will start to separate on the bottom of the bowl. This is the glair.

4. Pour the liquid into another vessel. Mix 1:1 with water to create the binder.
If gelatinous bits are floating in the glair, the liquid can be filtered through a fine sieve, but this may not be necessary.

5. On a glass palette mix 1:1 onion pigment to binder and mull until fully mixed. It is important that the pigment be a very fine grade. If it seems a bit course, grind the pigment in a mortar and pestle before mixing with the binder. UNLESS, the desired paint effect is more gritty.

6. Mull on a glass palette to be sure the pigment and binder are well mixed.

glair made from onion skin pigment

TEMPERA

Adapted from Caroline Ross and Robert Massey[2]

Note: Glair and Tempera paints shouldn't be stored. Only make as much as is needed to work for the day. Can be used on many substrates.

Materials:

- 1 egg yolk
- a fork or a beater
- a mixing bowl
- a glass palette and muller for mulling paint
- distilled water
- palette knife
- something to put the paint into when mixed (a small vessel)

1 Between the hands, roll back and forth an egg yolk. This will dry the egg sack.

2. With the fingers, pinch the egg sack and allow the liquid to pour into a vessel.

3. Add just a splash of water and beat with a fork. The consistency should be similar to a honey. The is the binder.

4. On a glass palette mix 1:1 onion pigment to binder and mull until fully mixed. It is important that the pigment be a very fine grade. If it seems a bit course, grind the pigment in a mortar and pestle before mixing with the binder. UNLESS, the desired paint effect is more gritty.

5. Mull on a glass palette to be sure the pigment and binder are well mixed.

Tempera made from onion skin pigment

LAKE PIGMENTS, GLAIR & TEMPERA

Takeaways

Meets the artists requirements of:

- affordable
- easily accessible
- can clean with water
- less smell than oil painting
- opaqueness (tempera)

Does not meet:

- less intimidating than oils
- opaqueness (glair)

Although the steps in this recipe are not complicated once practiced, it does seem intimidating.

Findings:

- The creation process, can be made with sunlight (except for the one step of heating the substance in the laking process to accept the alum) instead of over heat reducing impact with a biomimetic principle of using only sunlight.
- Traditionally lakes were made from plants, roots and barks. Using kitchen waste creates new opportunity for material use and waste reduction.
- If using egg shells as the calcium carbonate component, the only component that would need further research as far as a supply chain transparency would be the alum. The other materials are only eggs and water.
- Paper filters can be reused to make shifu papers or a color reference chart so there is no waste.
- Glair and tempera paints have been used in illuminated manuscripts which in some cases are still well preserved.
- Glair and Tempera paints do not have scalability since they should really be made to be used right away. The opportunity for more sustainable jobs would be for an artist to teach others how to create them.

Continued...

Takeaways

Findings Continued:

- Lake pigment making is scalable and does offer opportunities for “green” jobs as a pigment maker, especially if making pigments from local sources. There could be pigments makers from all over the world making pigments with what is only local to them.
- These recipes are not vegan, nor would they work for artists who have allergies to eggs. One vegan recipe was found in the research but was not tested. This would be an opportunity for further study.
- The glair and tempera binders can be stored in the refrigerator for a while (trust your nose, as Caroline Ross says). Once it smells off, it can be put in the compost.
- The alum makes the waste from the laking process (aside from the onion skins only) unable to go in the compost bin since it’s a synthetic metallic salt. Following examples in research of what can be done with pickles in composting. It’s possible that the paints, if it’s a small amount could still go in the compost bin if diluted with water. This still needs to be research further.
- Mayan blue is created using indigo dye powder bonded to kaolin clay over heat. It’s a simple recipe with only 2 ingredients and heat and no additives. It’s worth researching further if other botanical/vegetable colorants could be bonded to clay in this way since it would eliminate the synthetic metallic salt, alum.

EARTH PIGMENT, WATERCOLOR & GOUACHE

EARTH PIGMENTS

These recipes adapted from Lucy Mayes and Caroline Ross

Materials:

- A small bit of soft stone
- 2 jars
- a sieve
- coffee filters
- distilled water
- Mortar and pestle
- glass palette and muller
- palette knife
- mask*

*A rock in your hand is not the same as the same rock that you would pulverize in a mortar and pestle, and then use to make paint. As long as you are not in a contaminated area picking up rocks with your bare hands is usually regarded as safe. But crushing rocks is very different because it creates dust. You may be harmed by fine dust in the following ways:

1. All types of dust, including those officially classified as "non-toxic," can harm your lungs by obstructing the tiny air sacs in your lungs.
2. Heavy metal-containing dusts have been linked to cancer, blindness, severe neurological damage, and other diseases.

7

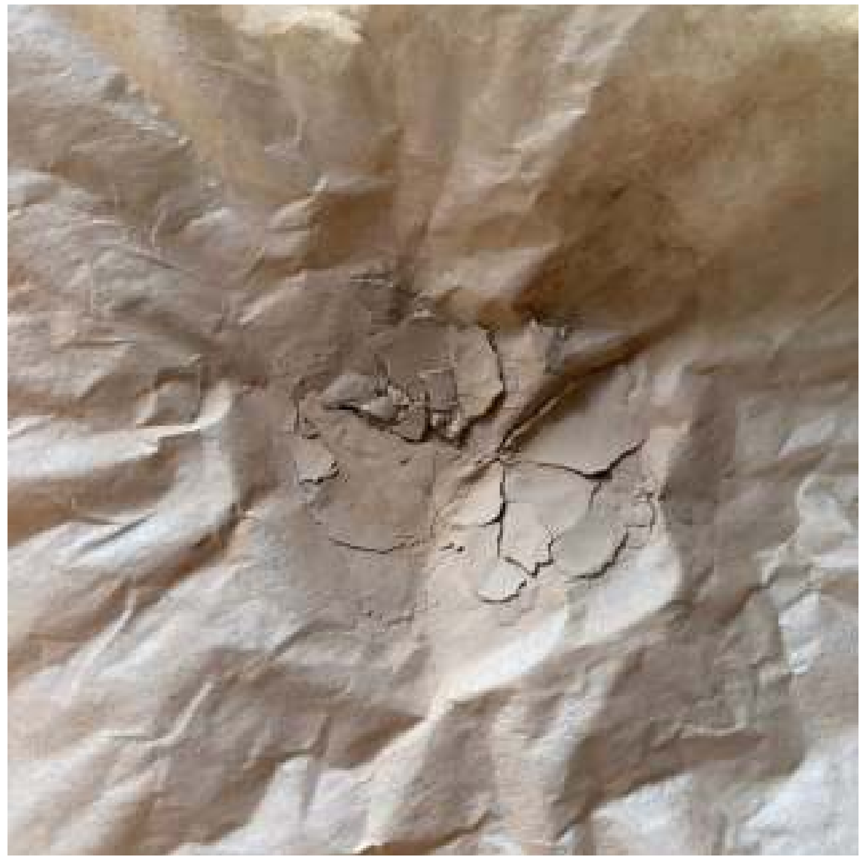
1 Crush with mortar and pestle, grind stone as much as possible into a fine particle size.

2. Sieve to get rid of larger bits of stone that will not break down, vegetable matter, or impurities. Larger bits can go back to where they were found. Grind pigment further if necessary.

3. Put in a jar and add up to half a jar of water.
4. Shake to get into full particle suspension.

5. Shake, counting to 5 and pour most of the liquid into another jar leaving the heavy material on the bottom of the first jar. The pigment will float, suspended in the first pour of the water, while the heavier particles will remain in the bottom of the first jar.

6. Pour the new liquid with the pigment into a coffee filter and let strain & dry.



Dried Pigment

WATERCOLOR PAINT

Adapted from Caroline Ross

Materials:

- Bowl
- Fork
- Honey (locally sourced)
- Powdered Gum arabic (if not powdered, it will have to be ground with a mortar and pestle)
- Distilled water
- Strainer
- Glass Palette & Muller
- Jar to put the binder mixture
- Clove or Wintergreen oil for an antifungal - optional
- Palette Knife

Creating the gum arabic and honey binder

In a jar to 1 part powdered gum arabic to 3 parts boiling water and mix until completely dissolved. To mixture add 1/5 honey (aim is 1 part honey to 5 part solution (or less)) and stir until completely dissolved. The honey allows the paint to be rewettable.

1 On a glass palette mix 1:1 pigment and gum arabic binder.

2 Mull paint until completely blended.

GOUACHE

Adapted from Caroline Ross

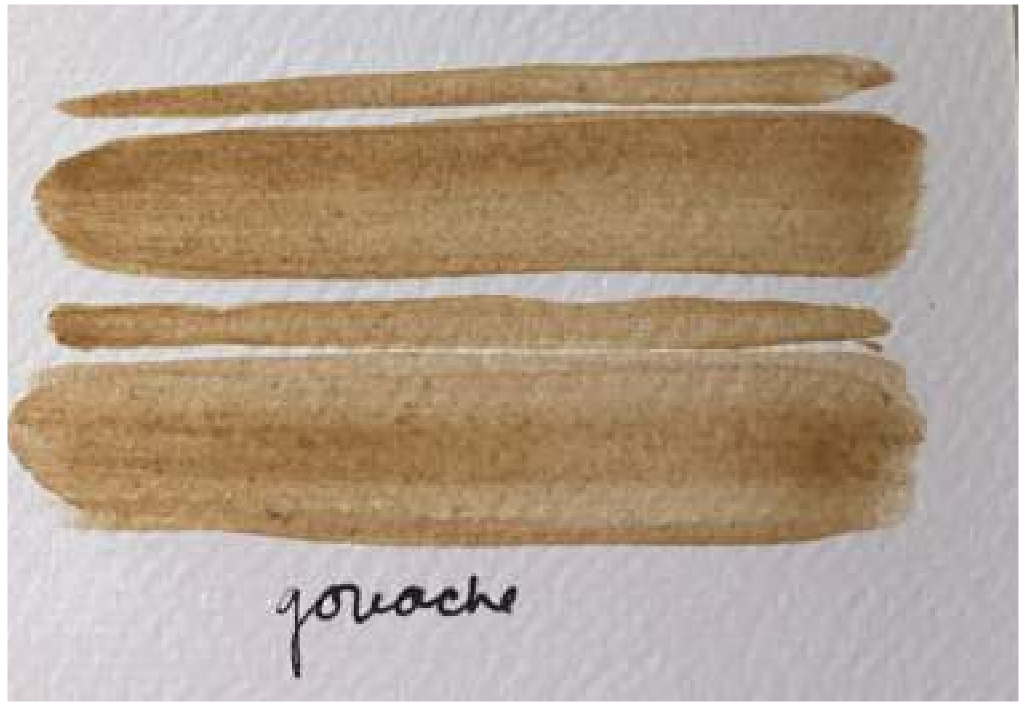
Materials:
Same ingredients and materials as watercolor paint except adding a white filler. Some options are:

- chalk
- egg shells
- marble dust
- limestone
- commercial food grade calcium carbonate
- cuttlefish bone

1 On a glass palette mix:

- 1 part pigment
- 1/2 part white filler (chalk, egg shells, marble dust, calcium carbonate, etc)
- 1 1/2 part water

2. Mull paint until completely blended.



EARTH PIGMENTS, WATERCOLOR & GOUACHE

Takeaways

Meets the artists requirements of:

- affordable
- easily accessible
- can clean with water
- less smell than oil painting
- opaqueness (gouache)

Does not meet:

- less intimidating than oils
- opaqueness (watercolors)

Findings:

- The creation process, can be made with sunlight (except for the one step of heating the water to mix the gum arabic (resin)) instead of over heat reducing impact with a biomimetic principle of using only sunlight.
- Gum arabic has been used for centuries and is a resin from an acacia tree found native to many counties in sub-saharan Africa and is facing overharvesting. The harvesting of this sap is often carried out by local families (including children) and seasonal and nomadic workers for low pay as well. Alternatives found in research was cherry tree gum, plum tree gum, and possible other fruiting trees. Conifer tree sap was found to not be optimal as it does not harden enough for the intended use in paints.[26]
- Safety is priority. Even the most knowledgeable geologists can't always identify every stone by sight. Be sure to wear a mask.
- These recipes are most like water based artist mediums that artists are already familiar with.
- Aside from dry pigments, these paints have the most stable shelf life.
- More research needed to know for sure the end of life possibilities due to the gum arabic resin (or other resins). It would also depend on the pigment used and the white filler used if creating gouache.

LEARNINGS

Pulling together the recipes and materials needed to make the paints myself felt daunting. Fun, but daunting. It took a while to find the information since there really aren't a lot of artists who are making their own paints, and there's even less scientific information on any of it. When artists did make their own paints, the knowledge was passed down to apprentices who would mix the paints for the artist as part of their learning. Eventually, colourmen became the people who made the colors for the artists. Soon there was a complete separation from artist and their paint materials, and the information seemed to become proprietary.

Fortunately, between the homesteading movement and the sustainable fashion movement there are a few niche communities making inks, dyes and a small handful making paints. Between these communities and some historical texts, I was able to source enough recipes to start to give it a try.

I must admit, I had a lot more fun once I got started. I felt quite intimidated at first, afraid I would mess it all up. But once I saw that there really wasn't any "messing it up", it was fun being a scientist in my art studio. I really enjoyed going to the dye garden, choosing the flowers, making ink out of them and making art from that ink. When posting pictures of the sketches I did with the ink on Instagram, I immediately received great feedback and interest in knowing more about the process.

Some quick takeaways:

- Making ink was easier than having to make a pigment first before making paints.
- Inks and Pigments made with the flowers have to be kept away from light
- Anything made with flowers (inks, paints) should be tested for lightfastness so the artist has an idea of how it will change with light. Paint a piece of paper, cover half of it and put it in a window. Watch to see how it changes.
- There is an opaque and a transparent lake pigment recipe. The one included here is the opaque recipe since it uses egg shells. But it should be known that there are two types of lake pigments.
- One teacher I studied with called the ink recipe included "botanical watercolors", another called it a "stain".
- This could be a really interesting global project to see artists all over the world creating paints from materials that are local to them.

UN SDGS

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

This project brought forth recipes for the artist which could eliminate the reliance on commercially available petroleum based paints in favor of making one's own placed based paints.

This process has the opportunity of putting the power back into the artists' hands of making responsible choices in their supply chain by intimately knowing every step along the way.

By having the artist create their own paints, it complete rethinks the industrial extraction, manufacturing, and paint making process and instead favors a more place-based artisanal process.

8 DECENT WORK AND ECONOMIC GROWTH

When an artist knows every ingredient in their paints (and their artwork) and they are able to make choices such as sourcing locally, renewably, and from responsibly managed sources they have the opportunity to contribute to healthy economic growth in their own community.

Beyond that, the artist themselves then becomes one of those local artisan businesses as well creating a responsibly sourced product.

14 LIFE BELOW WATER

Eliminating the use of petroleum based paints and art supplies out of the studio means eliminating microplastic waste that ends up in our oceans and waterways.

These recipes are water based media that do not contain microplastics, and would not contribute to the 7.4 million tonnes of microplastics leaked into the waterways each year.

CONCLUSIONS

While initially frustrated, during the observation phase in particular, that there just was no immediate replacement for acrylic paint, the lifecycle process and flows really brought to light the idea that maybe there shouldn't be a direct replacement.

The LCA showed that there could be 100% improvement if artists changed the way they created art all together. So it really became not just about replacing acrylic paint, but more about reimagining the way an artist creates.

For too long an artist has been able to dream up anything, walk into an art store and buy anything they could imagine to make it work. But what if an artist designed differently. What if they had to work with only materials they could create? New innovations and new ideas come out of limitations. After all, isn't that what we are all doing here now. It's no longer "business as usual". We need to look at what nature has to offer, recognize it's limitations and look for creative solutions. In the end, that's what this project is asking the artist to do.

Eliminating acrylic paint isn't the end of creative freedom. I'd argue that it's actually the beginning (or maybe the return?).

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Photos are that of the author unless otherwise noted

Component	Natural Environment	Raw Material Extraction			Material Processing		
	Where does it come from?	Virgin Material	Input/Output	Detail	Process	Input/Output	Detail
Acrylic Polymer for Acrylic Paint = polymethyl acrylate	Farmland, Arctic, Persian Gulf, Gulf of Mexico	Crude Oil- Horizontal drilling or hydraulic fracturing	Input	Hydraulic fracturing uses huge quantities of water mixed with chemicals.	Refinery - fractional distillation and chemical processing [11]	Input	crude oil
			Input	fuel for machinery		Input	energy - uses large amounts of energy and heat
			Output	pipelines also cause habitat destruction when being laid		Output	PRODUCT: Refinery Gases, Kerosene, deisel, gasoline blending components, naptha, lubricating oils, kerosene, residue (such as asphalt), residual fuel oil, refinery gases
			Output	Industries store this waste in open-air pits or underground wells that can leak or overflow into waterways and contaminate aquifers		Output	Reduced access for local people to uncontaminated freshwater supplies and can result in a local area suffering from water stress.
			Output	Harmful air pollutants can be emitted before fuels are even burned.		Output	Emissions from fossil fuels for energy for production processes.
			Output	Land use and stress on natural ecosystems from drilling and open pit excavation.		Output	Oil refineries are major sources of toxic air pollutants, including cancer-causing benzene, particulate matter, nitrogen oxides, carbon monoxide, and sulfur dioxide.[8]
			Output	Destruction of vegetation and soils when land is cleared for mining, road/camp building		Output	Refinery pollution contributes to existing racial and socio-economic health disparities in Washington, such as higher asthma prevalence among Black and Native American people according to an article about the Northwest Refinery in Washington State due to the socio-economic area the refinery is located in.[8]
			Output	Emissions from heavy equipment needed.		Output	Even after treating the wastewater, there may still remain a variety of pollutants, including sulfides, ammonia, and other oil residuals. The EPA sets limits for the concentration of pollutants that can remain in treated wastewater. These limits, however, are based on what is technologically feasible, not what may be damaging to the environment.[8]
			Output	Regular oil leaks and spills contaminate land and water, endanger wildlife, destroy habitats, force communities to evacuate, and cause health issues.		Output	dangerous work around chemicals for employees [9]
			Input	pipelines also cause habitat destruction when being laid		Output	dangers of fires
			Input			Output	acid rain and acidification caused by fossil fuel combustion
			Input			Output	Some adverse health effects living near a refinery include: increased risk of asthma, cancers, birth defects, neurological damage, cardiovascular damage, difficulty breathing, and blood disorders.[9]
			Input			Output	sulfer oxides [10]
			Input			Output	Due to inadequate city planning and disparities in wealth, minority groups are disproportionately impacted by the harmful effects of refineries and frequently forced into the front lines of conflict.These families are unable to relocate from these contaminated areas due to high rates of poverty. Minority communities usually have restricted access to medical care and treatment, which exacerbates the situation.[9]

Component Manufacturing			Assembly & Packaging			Transport/Distribution/Purchase		
	Input/Output	Detail		Input/Output	Detail		Input/Output	Detail
naptha - through Additional polymerisation and Compounding/Processing	Output	PRODUCT: an acrylic polymer in pellet or powdered state likely	uncertain on how this is packaged	Output	likely plastic and cardboard packaging waste	transport to paint making factory + Transport to retailer + transport to studio	Input	fuel for transportation via road or air
	Input			Input			Output	Pollutants that contribute to poor air quality include particulate matter (PM), nitrogen oxides (NOx), and volatile organic compounds (VOCs). [12]
	Input			Input			Output	mircoplastics from tires on the road
	Input			Input			Output	
	Input			Input			Output	
	Input			Input			Input	
	Input			Input			Input	
	Input			Input			Input	
	Input			Input			Input	

Use Phase			Maintenance/Upgrading			End of Life Scenarios		
	Input/Output	Detail		Input/Output	Detail		Input/Output	Detail
acrylic polymer	Input	**Pigments:** Can be Natural or Synthetic.				Landfill	Input	paint tubes, brushes, canvases, used paper towels, rags
	Input	**Solvent:** Oxygenated solvents: glycols derived from petroleum .[13]				Landfill	Output	micro plastic leaching into waterways affecting aquatic life and human life
	Input	**Water:** unclear where this is sourced or how/if it is refined.				Other	Input	paint tubes, used rags (should be sent to hazardous waste)
	Input	**Additive:** Plasticizer from polyethylene glycol. (derived from petroleum) [15]				Disassembly	Input	
	Input	**Additive:** Stabilizer/Surfactant (Surface Active Agent) - can be toxic to animals and the environment [14]				Disassembly	Input	
	Input	**Additive:** Thickener/Thinner: Many on the market including alginic acid, agar, carrageenan, pectin and gelatin. [13]				Disassembly	Input	
	Input	**Additive:** Preservatives/Biocides including formaldehyde donors. [13]				Disassembly	Input	
	Output	Acrylic Paint				Disassembly	Input	
Inside the painter studio	Output	Paper towel/rag waste from acrylic paints				Disassembly	Input	
	Output	acrylic Paint Water Waste				Disassembly	Input	
	Output	Microplastics in the oceans and waterways affecting oceanlife and human life from acrylic paint				Disassembly	Input	
	Output	Dried paint brushes				Disassembly	Input	
	Output	Acrylic Paint waste				Disassembly	Input	
	Output	Packaging waste = unused, dried up, and/or empty paint tubes (plastic or tin mostly)				Disassembly	Input	
	Output	Energy waste for studio lights				Disassembly	Input	
	Input					Disassembly	Input	

Other phases remain the same as the Acrylic Polymer Lifecycle Process and Flow Diagram as it partners up to make paint through to End of Life

Component	Natural Environment	Raw Material Extraction			Material Processing		
	Where does it come from?	Virgin Material	Input/Output	Detail	Process	Input/Output	Detail
Titanium White - Global TiO_2 pigment demand for 2010 was 5.3 Mt with annual growth expected to be about 3-4% (wikipedia)	ORE -**Ilmenite** most commonly, but less "pure" than something like rutile. Thus creating a **synthetic Titanium dioxide**. It is a weakly magnetic mineral sand, grey-black in color, solid in form, and exists in a triangle crystal structure	Dry mining or hard rock mining depending on location	Input	Energy for Jaw crusher, ball mill, magnetic separator, spiral separator, spiral chute, dryer, vibrating feeder, vibrating conveyor, etc.	Chloride Process - the ore is treated with chlorine and carbon to give titanium tetrachloride, a volatile liquid that is further purified by distillation. The TiCl4 is treated with oxygen to regenerate chlorine and produce the titanium dioxide. (considered by some to be a more "environmentally acceptable" process. [17]	Input	Chlorine. About one ton of chlorine is required to produce 5 to 6 tons of titanium dioxide pigment
	Ilmenite supplies about 91% of the world's demand for titanium minerals, being its world production of about 5.3 million metric tons in 2009		Input	Oil to run machines		Input	*Finally the pure titanium dioxide is subjected to a range of chemical surface treatments, milling and drying.* ?
			Input	water for washing materials		Input	water
	ORE - Rutile is reddish-brown in color and exists in a tetragonal crystal structure		Output	harming fragile coastal areas		Input	Energy to run a fluidized bed reactor & a plasma arc furnace
			Output	deforestation - topsoil is replaced by tailings from mining resulting in loss of trees and plants [18]		Input	petroleum coke as a reducing agent
	More than half of the world's titanium production is from ilmenite and rutile in shoreline placer deposits in Australia, South Africa, USA, India and Sri Lanka. Most of the remainder is supplied by magmatic ilmenite deposits in Canada, Norway, M. J. Gázquez et al. 444 Finland and USA. The magmatic deposits yield ilmenite with a TiO2 content of 35% - 40%, whereas the **shoreline placer deposits** provide ilmenite of higher TiO2 content, including altered ilmenite (60% - 75% TiO2), leucoxene (76% - 90% TiO2) and rutile (95% TiO2) [11].		Output	pollution of ground water resources from abandoned mines and improper rehabilitation of mineral-sand deposits [18]		Output	the production of titanium dioxide is a NORM (Naturally Occurring Radioactive Material) industrial process, because of ilmenite present enhanced levels of natural radionuclides from both uranium and thorium series. Some of these radionuclides can be found enriched in the co-products and waste generated [27]
			Output	elevated radiation hazards		Output	The wastes generated by the chloride process are mainly coke and ore solids that remain un-reacted during the chlorination process. In addition a waste acid solution, usually called iron chloride waste acid, is also generated when the combined stream of un-reacted coke and ore solids, metal chloride solids, is acidified using water or waste hydrochloric acid (HCl) from the reaction scrubber. The metal chloride impurities are generally environmentally harmful, especially the iron chloride, which are removed and neutralized with lime or limestone, and finally sent for disposal via landfill. [27]
			Output	In Vietnam, deforestation of coastal areas results in removing barrier needed to protect local people from storms, devastated the floral carpet, depleted underground water sources, and created sandy mountains looking like uneven scars along the coastline, loss of poplar forests acting as a shield to protect the village has dried out hills and caused sand from the mines to fill up irrigation canals, sandy rice fields and gardens [20]	Sulfate Process - Chemical manufacturing plants using the sulfate process, require ilmenite concentrate (45–60% TiO_2) or pretreated feedstocks as a suitable source of titanium.[30] In the sulfate process, ilmenite is treated with sulfuric acid to extract iron(II) sulfate pentahydrate. The resulting synthetic rutile is further processed according to the specifications of the end user, i.e. pigment grade or otherwise. [17]	Input	water & sulfuric acid & iron/scrap metal [27]
			Output	socio-economic exploitations by mining companies to local communities [19]		Input	The dried titanium dioxide is sent to a finishing phase, which involves any required milling and or chemical treatment, such as surface coating with silica or alumina. Further processing (finishing), is then analogous to the chloride process involving chemical surface treatments (coating), milling and drying operations. [27]
			Output	land use to support infrastructure of mining system [16]		Output	the production of titanium dioxide is a NORM (Naturally Occurring Radioactive Material) industrial process, because of ilmenite present enhanced levels of natural radionuclides from both uranium and thorium series. Some of these radionuclides can be found enriched in the co-products and waste generated [27]
			Output	Releases bioavailable materials to be absorbed by plants and animals in the area? - do more research on this.		Output	acidic Waste water can potentially be dumped into waterways depending on government regulations. (In Spain deep sea deposits were allowed until 1993).
			Output	High water use in mining operations can lead to reduced access for local people to uncontaminated freshwater supplies and can result in a local area suffering from water stress.[16]		Output	Impact Health of Employees: Considered a class 2 carcinogenic as of 2020 by the EU if inhaled. And group b carcinogen by International Agency for Research on Cancer. When a product contains more than 1% of titanium dioxide particles in powder form with an aerodynamic diameter of ≤ 10 μm, the product needs to be labelled as a hazardous substance. In a production facility, titanium dioxide can create an occupational hazard through inhalation, as well as through eye and skin contact, when it enters the air and contaminates surfaces. At high concentrations, particles can irritate the nose and throat, creating an unsafe environment for facility workers. Long-term exposure may even cause bronchitis, resulting in symptoms such as coughing, phlegm, and/or shortness of breath. [25]
			Output	Waste water and tailings, which can be laden with heavy metals, radioactive materials, and other pollutants.[16]			
			Output	artisanal mining practices [19]			

Other phases remain the same as the Acrylic Polymer Lifecycle Process and Flow Diagram as it partners up to make paint through to End of Life

Component	Natural	Raw Material Extraction			Material Processing			Component Manufacturing		
	Where does it come from?	Virgin Material	Input/Output	Detail	Process	Input/Output	Detail		Input/Output	Detail
Quinacridone Pigments - Synthetic organic pigments are carbon based molecules manufactured from petroleum compounds, acids, and other chemicals, usually under intense heat or pressure. The techniques for producing these substances on an industrial scale were invented after 1860, which created the modern era of consumer color. Chemical and industrial innovations increased at an astonishing pace through the end of the 19th century and have continued up to the present.	Farmland, Arctic, Persian Gulf, Gulf of Mexico	Crude Oil- Horizontal drilling or hydraulic fracturing	Input	Hydraulic fracturing uses huge quantities of water mixed with chemicals.	Refinery - fractional distillation and chemical processing [11]	Input	crude oil	terephthalic acid derived from turpentine - This white solid is a commodity chemical, used principally as a precursor to the polyester PET, used to make clothing and plastic bottles. [22]	Input	Condensation of succinosuccinate esters with aniline followed by cyclization affords dihydroquinacridone, which are readily dehydrogenated. (aniline is derived from coal tar). [23]
			Input	fuel for machinery		Input	energy - uses large amounts of energy and heat		Output	aniline is toxic to humans [21]
			Output	pipelines also cause habitat destruction when being laid		Output	PRODUCT: Refinery Gases, Kerosene, deisel, gasoline blending components, naptha, lubricating oils, kerosene, residue (such as asphalt), residual fuel oil, refinery gases		Output	PRODUCT: aniline dyes (Notes: this family of dyes was the azo dyes - also synthetic). [21]
			Output	Industries store this waste in open-air pits or underground wells that can leak or overflow into waterways and contaminate aquifers		Output	Reduced access for local people to uncontaminated freshwater supplies and can result in a local area suffering from water stress.	It is well known in the art that organic pigments, such as quinacridones, as synthesized, are generally unsuitable for use as pigments and must be further processed to develop the requisite pigmentary properties such as particle size, particle shape, polymorphic phase, and tinctorial strength.In order to obtain the color properties required for a particular application, the pigment crude must be converted to a pigmentary grade with	Input	Finishing Process: "Pigment Crude" requires finishing = by m pigment powder in the presence of large amounts of inorga metal rails and/or balls. In this process, pigment crude is t almost amorphous phase, followed by a re-growth process achieve the proper crystal size. This milling of pigment cru the re-crystallization makes this finishing process complic [24]
			Output	Harmful air pollutants can be emitted before fuels are even burned.		Output	Emissions from fossil fuels for energy for production processes.		Input	Finishing Process: "Pigment Crude" requires finishing = by a dissolved in a strong acid such as sulphuric acid, often in th polar organic solvent. Then the pigment is drowned out an into an appropriate particle size designed for a particular ap
			Output	Land use and stress on natural ecosystems from drilling and open pit excavation.		Output	Oil refineries are major sources of toxic air pollutants, including cancer-causing benzene, particulate matter, nitrogen oxides, carbon monoxide, and sulfur dioxide.[8]		Output	the dry milling process requires the presence of inorganic s crystallizationin strong acid, generating significant environ
			Output	Destruction of vegetation and soils when land is cleared for mining, road/camp building		Output	Refinery pollution contributes to existing racial and socio-economic health disparities in Washington, such as higher asthma prevalence among Black and Native American		Output	The dissolution process similarly generates large quantities [24]
			Output	Emissions from heavy equipment needed.		Output	Even after treating the wastewater, there may still remain a variety of pollutants, including sulfides, ammonia, and other oil residuals. The EPA sets limits for the concentration of		Output	considerable energy cost
			Output	Regular oil leaks and spills contaminate land and water, endanger wildlife, destroy habitats, force communities to evacuate, and cause health issues.		Output	dangerous work around chemicals for employees [9]		Input	additional pigments to create the precise color needed
			Input	pipelines also cause habitat destruction when being laid		Output	dangers of fires		Input	
			Input			Output	acid rain and acidification caused by fossil fuel combustion		Input	
			Input			Output	Some adverse health effects living near a refinery include: increased risk of asthma, cancers, birth defects, neurological damage, cardiovascular damage, difficulty breathing, and blood disorders.[9]		Input	
			Input			Output	sulfer oxides [10]		Input	
			Input			Output	Due to inadequate city planning and disparities in wealth, minority groups are disproportionately impacted by the harmful effects of refineries and frequently forced into the front lines of conflict.These families are unable to relocate from these contaminated areas due to high rates of poverty. Minority communities usually have restricted access to medical care and treatment, which exacerbates the		Input	
			Input			Input			Input	

40,000 years ago, primitive artists invented the first pigments, painting cave walls using a combination of soil, animal fat, minerals, charcoal, and chalk.[3]

Into the Middle Ages and the Renaissance, artists were still mixing their own paints in their studio.

Da Vinci's Studio at Le Clos Lucé 1515-1519

It wasn't until the first industrial revolution, in 1840, that colourmen Winsor Newton bought the first patent on metal tubes and virtually gave rise to the Impressionist movement allowing the artist the ability to move outside their studio to paint with portable paint that would last much longer than before.[4] The colourmen also allowed the artist to focus more on the painting and less on the creation of the paints. The colourmen became the scientists of color and the place to buy paints instead of making them in your own studios.

As their understanding of chemistry advanced, scientists began trying to create synthetic colors in a lab. In 1865, just shortly after the metal paint tubes came into circulation,

William Henry Perkin accidentally discovered the first commercialized synthetic dyestuff from chemicals derived from coal tar, which he called mauveine (or aniline purple). This discovery was the basis for a whole new chemical industry of synthetic dyes and pigments. "Before the 1800s, most dyes were organic; they came from plants, insects, or minerals harvested from nature. But then came synthetics—dyes made in the laboratory. For the first time, we could create colors rather than imitate them."[5]

In the 1950s, when acrylic paints became popular, artists could paint images of nature (or even protest deforestation) using paints with binders derived from fossil fuels with synthetic pigments of all colors imaginable also derived from fossil fuels. While the waste water from the studio is dumped down the drain from the supposed water-soluble paint and microplastics continue to accumulate in the ocean and are continuing to affect ocean life and even human life on a scale that is still trying to be understood.

In just a short 200 years, compared to the several thousand that humans have been painting, the advancements that have been made have completely disconnected the artist from the natural world to the point where they don't know where their paints come from, nor do they know what the actual impact of their choices are making on the health of humans or the biosphere.

What are lake pigments?

A lake pigment is a pigment made by precipitating a dye with an inert binder.

Lake pigments have a long history in decoration and the arts. Some have been produced for thousands of years and traded over long distances.

- Indigo lake was first made from woad leaves and was well-known in ancient Egypt. Woad was popularized as a textile dye in the late Middle Ages, which resulted in overplanting and soil fatigue in many regions of Europe. The opening of trade routes to the east resulted in the importation of indigo from India, which replaced woad and made its cultivation unprofitable in Europe. Currently, most of the dark blue dye known as indigo, which was formerly made from woad and Indigofera tinctoria, is synthetic.

- Rose madder lake is from the root of the madder plants. It's synthetic form is known as alizarin crimson. Because rose madder fades quickly in the presence of light, quinacridone pigments have largely replaced the use of rose madder.

- The cochineal insect, which is indigenous to Central and South America, was the original source of carmine lake, also known as crimson lake. The organic substance that gives carmine its color, carminic acid, was created in 1991.

Indigo and rose madder are now produced more cheaply from synthetic sources, although some use of natural products persists, especially among artisans.[28]

REFERENCE

Acrylic Painting - 10 paintings, size 16x20 inches

Commercially available acrylic paints & canvases manufactured overseas

Project:	Acrylic Painting
Concept:	Acrylic Painting on Canvas - baseline for 10 16x20 paintings
Methodology	SM 2013
Date:	
Created by:	
Total Amoun	10 x 1 year of use

Item	S	Row type	P	Name	Description	Qty	Material/pro	Amount	Units	Measuremer	Total (mpt	Acidification	Ecotoxicity (r	Eutrophicatio	Global warm	Ozone deple	Fossil fuel d	Carcinogenic	Non carcinog	Respiratory e	Smog (mpts)	CO2 Equivalent (kgs)
0		concept		Acrylic Painting on Canvas - baseline for 10 16x20 paintings							1.82	0.0425	0.207	0.0614	0.185	0.000137	0.0761	1.06	0.104	0.0478	0.0372	12.8
1		Life cycle stage																				
1.1		Part		Staples		400		0.1	oz													
1.1.1		Material proce		Process			Wire drawin	0.1	oz	Estimate	0.0655	6.94E-05	0.000848	2.74E-05	0.000627	5.89E-07	0.000189	0.0198	0.000309	8.99E-05	5.64E-05	0.0435
1.1.2		Material		Staples			Stainless ste	0.1	oz	Estimate	1.29	0.0016	0.0268	0.000355	0.00895	5.56E-06	0.00341	0.59	0.0281	0.00612	0.00131	0.621
1.2		Part		Canvas		10		11	oz													
1.2.1		Material		Canvas			Woven cotto	11	oz	Estimate	9.63	0.0311	0.17	0.0551	0.126	3.13E-05	0.0225	0.355	0.058	0.0326	0.0214	8.75
1.3		Part		Pigment - TiO2		10		8	oz													
1.3.1		Material		Pigment - TiO2			Titanium dio	8	oz	Estimate	1.11	0.00306	0.00298	0.000914	0.015	3.02E-05	0.0138	0.0224	0.00702	0.00325	0.00246	1.04
1.4		Part		Pigment - Carbon Black		10		2	oz													
1.4.1		Material		Pigment - Carbon Black			Carbon black	2	oz	Estimate	0.146	0.000154	0.000178	4.81E-05	0.00197	1.47E-05	0.00475	0.00152	0.000236	0.000388	0.000175	0.137
1.5		Part		Acrylic Varnish to Seal		10		2	oz													
1.5.1		Material		Acrylic Varnish to Seal			Acrylic varni	2	oz	Estimate	0.129	0.000237	0.000525	0.000259	0.0017	2.66E-06	0.00174	0.00511	0.000864	0.000229	0.000221	0.118
1.6		Part		Acrylic Gesso (Base Coat)		10		4	oz													
1.6.1		Material		Acrylic Gesso (Base Coat)			Acrylic varni	4	oz	Estimate	0.258	0.000474	0.00105	0.000519	0.0034	5.32E-06	0.00349	0.0102	0.00173	0.000459	0.000442	0.236
1.7		Part		Stretcher Bars		10		1.38	oz													
1.7.1		Material proce		Process			Wood, planir	1.38	lbs	Estimate	0.0298	7.62E-05	9.30E-05	1.59E-05	0.000399	2.07E-07	0.000123	0.00107	0.000219	6.37E-05	4.94E-05	0.0277
1.7.2		Material		Stretcher Bars			Pitch pine	1.38	oz	Estimate	0.0132	6.81E-05	0.00024	3.10E-05	0.000171	3.32E-08	0.000161	0.00033	9.66E-05	1.43E-05	0.000166	0.0119
1.8		Part		Acrylic Binder to bind pigment		10		8	oz													
1.8.1		Material		Acrylic Binder to bind pigments			Acrylic binde	8	oz	Estimate	0.401	0.000656	0.00155	0.000419	0.00523	5.09E-06	0.00704	0.0205	0.00185	0.000642	0.000569	0.363
1.9		Part		Pigment - Cadmium		10		2	oz													
1.9.1		Material		Pigment - Cadmium			Cadmium, pr	2	oz	Estimate	0.0723	0.00019	0.000261	3.50E-05	0.000964	5.24E-07	0.0003	0.00298	0.000486	0.000157	0.000123	0.0668
2		Life cycle stage																				
2.1		Water use		Water			Tap water, a	20	gal	Estimate	0.00355	8.18E-06	1.30E-05	1.61E-06	4.75E-05	2.43E-08	1.38E-05	0.000136	2.14E-05	6.90E-06	5.86E-06	0.00329
3		Life cycle stage																				
3.1.1		End of life		Landfill, steel		400	Stainless ste	0.1	oz	Estimate	0.000929	2.58E-06	1.63E-06	1.93E-06	1.24E-05	4.80E-08	2.02E-05	1.66E-05	2.53E-06	2.98E-06	6.07E-06	0.000862
3.1.2		End of life		Landfill, sanitary, generic		10	Woven cotto	11	oz	Estimate	0.00183	6.19E-06	2.12E-06	4.35E-06	2.49E-05	3.64E-08	2.01E-05	2.30E-05	3.55E-06	8.39E-06	1.41E-05	0.00173
3.1.3		End of life		Landfill, sanitary, generic		10	Titanium dio	8	oz	Estimate	0.00133	4.51E-06	1.55E-06	3.16E-06	1.81E-05	2.65E-08	1.46E-05	1.68E-05	2.58E-06	6.10E-06	1.02E-05	0.00126
3.1.5		End of life		Landfill, polyurethane		10	Acrylic varni	2	oz	Estimate	0.00602	3.69E-06	5.64E-06	0.000236	8.12E-05	3.74E-08	1.71E-05	3.44E-05	5.23E-06	3.46E-06	6.28E-06	0.00563
3.1.6		End of life		Landfill, polyurethane		10	Acrylic varni	4	oz	Estimate	0.012	7.38E-06	1.13E-05	0.000472	0.000162	7.47E-08	3.43E-05	6.89E-05	1.05E-05	6.92E-06	1.26E-05	0.0113
3.1.7		End of life		Landfill, wood		10	Pitch pine	1.38	oz	Estimate	0.00263	1.62E-06	1.32E-06	5.98E-06	3.67E-05	2.42E-08	1.09E-05	1.54E-05	2.23E-06	1.92E-06	3.50E-06	0.00255
4		Life cycle stage																				
4.1		Transportation - Assembled product																				
4.1.1		Transportation - Assembled product				1	Freighter, oc	11350	km	Estimate	0.168	0.00134	0.000207	0.000477	0.00227	3.29E-06	0.00182	0.00193	0.000356	0.000912	0.00169	0.157
4.1.2		Transportation - Assembled product				1	Truck, 20-28	3800	km	Estimate	1.01	0.00266	0.0023	0.00192	0.0136	2.85E-05	0.0128	0.0231	0.00345	0.00212	0.00652	0.944
4.1.3		Transportation - Assembled product				1	Truck, 20-28	1140	km	Estimate	0.304	0.000797	0.000691	0.000677	0.00408	8.56E-06	0.00385	0.00693	0.00103	0.000637	0.00195	0.283

REFERENCE

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints & canvases manufactured overseas

Reference	This concept is the reference for this project. The reference is a baseline to which other concepts in this project will be compared.
Acrylic Painting on Canvas - baseline for 10 16x20 paintings	

Reference

Impacts per functional unit	**1.8** mPts per 1 year of use
Total amount of service delivered	10 x 1 year of use
Impacts of total service delivered	18 mPts
Assessment level	Estimate
Greatest impacts	
SBOM input	Woven cotton fabric
Impact category	Carcinogenics
Life cycle stage	Manufacturing

Total impacts by impact category

Impact category	%
Ecological damage	
Acidification	2.33
Ecotoxicity	11.38
Eutrophication	3.37
Global warming	10.15
Ozone depletion	0.01
Resource depletion	
Fossil fuel depletion	4.18
Human health damage	
Carcinogenics	58.22
Non carcinogenics	5.7
Respiratory effects	2.62
Smog	2.04

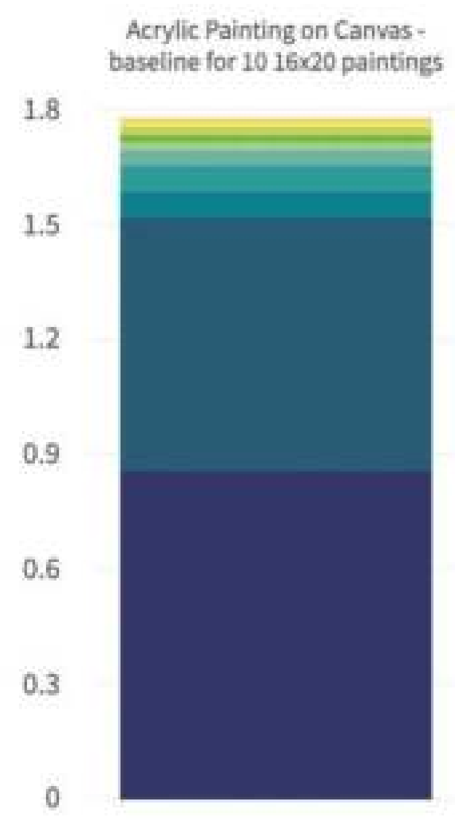
REFERENCE

Acrylic Painting - 10 paintings, size 16x20 inches

Commercially available acrylic paints & canvases manufactured overseas

Impacts by SBOM inputs: Total [mPts/func unit]

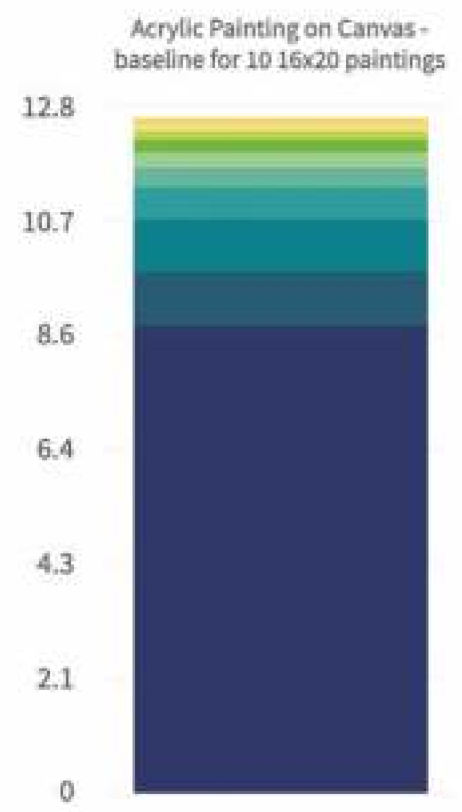
Reference



Total = 1.8mPts/func unit

Input	mPts/func unit
Material - Woven cotton fabric	0.872
Material - Stainless steel, austenitic	0.666
Material - Titanium dioxide, production mix, inorganic	0.0710
Transportation - Truck, 20-28t	0.0685
Material - Acrylic binder, 34% in H2O	0.0385
Process - : Wire drawing, steel	0.0220
Material - Acrylic varnish, 87.5% in H2O	0.0218
Transportation - Truck, 20-28t	0.0206
Transportation - Freighter, oceanic	0.0110
Material - Acrylic varnish, 87.5% in H2O	0.0109

Reference



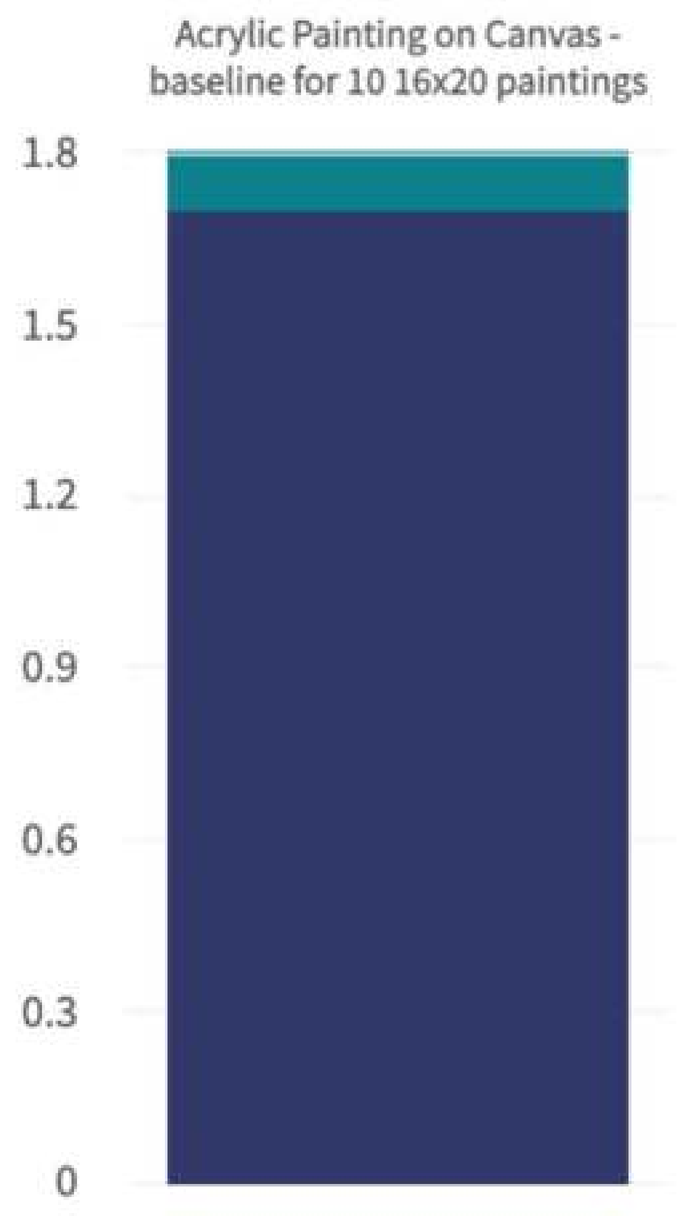
Total = 13 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118

REFERENCE

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints & canvases manufactured overseas

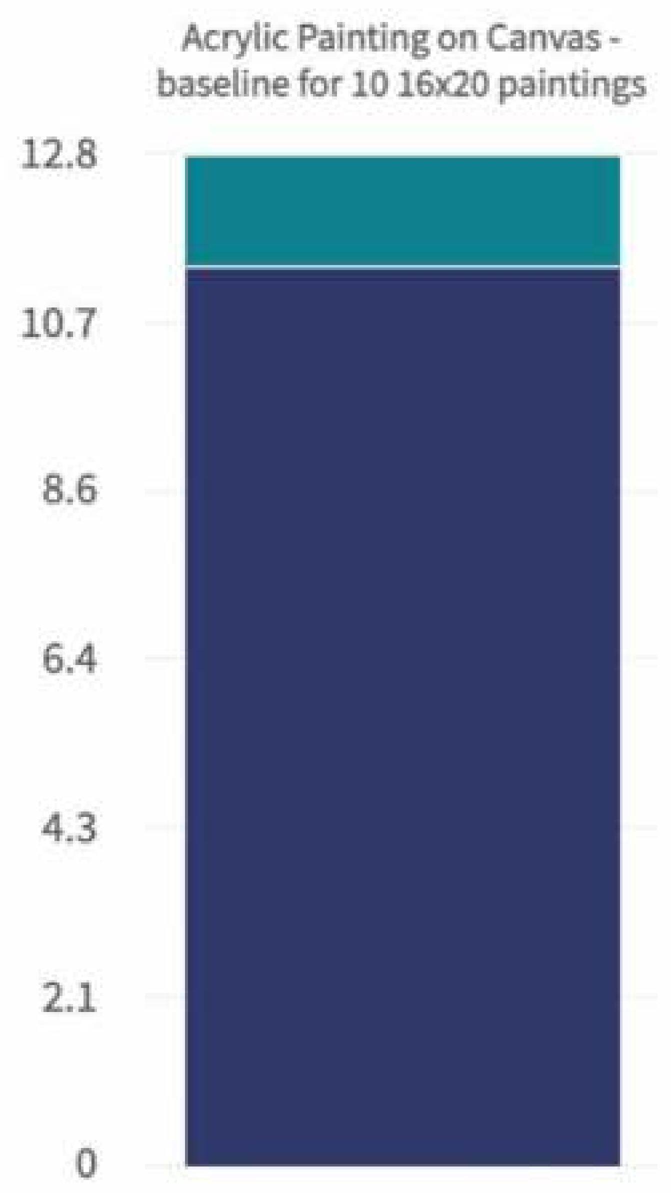
Reference



Total = 1.8mPts/func unit

Lifecycle stage	mPts/func unit
Manufacturing	1.72
End of life	1.51×10^{-3}
Transportation	0.100
Use	2.54×10^{-4}

Reference



Total = 13 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Manufacturing	11.4
End of life	0.0233
Transportation	1.38
Use	3.29×10^{-3}

CONCEPT 1

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints & canvases manufactured locally in Minneapolis.

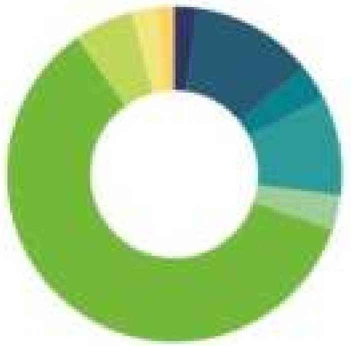
Project:	Acrylic Painting
Concept:	Locally Made Concept
Methodolog	SM 2013
Date:	
Created by:	
Total Amoun	10 x 1 year of use

Item	!	Row type	Pa	Name	Description	Qty	Material/pro	Amou	Units	Measuremer	Total (m	Acidification	Ecotoxicity (r	Eutrophicatic	Global warm	Ozone deple	Fossil fuel d	Carcinogenic	Non carcinog	Respiratory	Smog (mpts)	CO2 Equivalent (kgs)
0		concept		Locally Made Concept							1.72	0.0378	0.204	0.0585	0.165	9.65E-05	0.0576	1.03	0.099	0.0441	0.0271	11.4
1		Life cycle stage																				
1.1		Part		Staples		400		0.1	oz													
1.1.1		Material proces:		Process			Wire drawin	0.1	oz	Estimate	0.0655	6.94E-05	0.000848	2.74E-05	0.000627	5.89E-07	0.000189	0.0198	0.000309	8.99E-05	5.64E-05	0.0435
1.1.2		Material		Staples			Stainless ste	0.1	oz	Estimate	1.29	0.0016	0.0268	0.000355	0.00895	5.56E-06	0.00341	0.59	0.0281	0.00612	0.00131	0.621
1.2		Part		Canvas	Not indicate	10		11	oz													
1.2.1		Material		Canvas			Woven cotto	11	oz	Estimate	9.63	0.0311	0.17	0.0551	0.126	3.13E-05	0.0225	0.355	0.058	0.0326	0.0214	8.75
1.3		Part		Pigment - Ti	Placeholder	10		8	oz													
1.3.1		Material		Pigment - TiO2			Titanium dio	8	oz	Estimate	1.11	0.00306	0.00298	0.000914	0.015	3.02E-05	0.0138	0.0224	0.00702	0.00325	0.00246	1.04
1.4		Part		Pigment - Ca	Placeholder	10		2	oz													
1.4.1		Material		Pigment - Carbon Black			Carbon black	2	oz	Estimate	0.146	0.000154	0.000178	4.81E-05	0.00197	1.47E-05	0.00475	0.00152	0.000236	0.000388	0.000175	0.137
1.5		Part		Acrylic Varnish to Seal		10		2	oz													
1.5.1		Material		Acrylic Varnish to Seal			Acrylic varnis	2	oz	Estimate	0.129	0.000237	0.000525	0.000259	0.0017	2.66E-06	0.00174	0.00511	0.000864	0.000229	0.000221	0.118
1.6		Part		Acrylic Gesso (Base Coat)		10		4	oz													
1.6.1		Material		Acrylic Gesso (Base Coat)			Acrylic varnis	4	oz	Estimate	0.258	0.000474	0.00105	0.000519	0.0034	5.32E-06	0.00349	0.0102	0.00173	0.000459	0.000442	0.236
1.7		Part		Stretcher Ba	Medium wei	10		1.38	oz													
1.7.1		Material proces:		Process			Wood, planir	1.38	lbs	Estimate	0.0298	7.62E-05	9.30E-05	1.59E-05	0.000399	2.07E-07	0.000123	0.00107	0.000219	6.37E-05	4.94E-05	0.0277
1.7.2		Material		Stretcher Bars			Pitch pine	1.38	oz	Estimate	0.0132	6.81E-05	0.00024	3.10E-05	0.000171	3.32E-08	0.000161	0.00033	9.66E-05	1.43E-05	0.000166	0.0119
1.8		Part		Acrylic Binde	Estimate 4 t	10		8	oz													
1.8.1		Material		Acrylic Binder to bind pigments			Acrylic binde	8	oz	Estimate	0.401	0.000656	0.00155	0.000419	0.00523	5.09E-06	0.00704	0.0205	0.00185	0.000642	0.000569	0.363
1.9		Part		Pigment - Cadmium		10		2	oz													
1.9.1		Material		Pigment - Cadmium			Cadmium, pr	2	oz	Estimate	0.0723	0.00019	0.000261	3.50E-05	0.000964	5.24E-07	0.0003	0.00298	0.000486	0.000157	0.000123	0.0668
2		Life cycle stage																				
2.1		Water use		Water			Tap water, a	20	gal	Estimate	0.0036	8.18E-06	1.30E-05	1.61E-06	4.75E-05	2.43E-08	1.38E-05	0.000136	2.14E-05	6.90E-06	5.86E-06	0.00329
3		Life cycle stage																				
3.1.1		End of life		Landfill, steel		400	Stainless ste	0.1	oz	Estimate	0.0009	2.58E-06	1.63E-06	1.93E-06	1.24E-05	4.80E-08	2.02E-05	1.66E-05	2.53E-06	2.98E-06	6.07E-06	0.000862
3.1.2		End of life		Landfill, sanitary, generic		10	Woven cotto	11	oz	Estimate	0.0018	6.19E-06	2.12E-06	4.35E-06	2.49E-05	3.64E-08	2.01E-05	2.30E-05	3.55E-06	8.39E-06	1.41E-05	0.00173
3.1.3		End of life		Landfill, sanitary, generic		10	Titanium dio	8	oz	Estimate	0.0013	4.51E-06	1.55E-06	3.16E-06	1.81E-05	2.65E-08	1.46E-05	1.68E-05	2.58E-06	6.10E-06	1.02E-05	0.00126
3.1.5		End of life		Landfill, polyurethane		10	Acrylic varnis	2	oz	Estimate	0.006	3.69E-06	5.64E-06	0.000236	8.12E-05	3.74E-08	1.71E-05	3.44E-05	5.23E-06	3.46E-06	6.28E-06	0.00563
3.1.6		End of life		Landfill, polyurethane		10	Acrylic varnis	4	oz	Estimate	0.012	7.38E-06	1.13E-05	0.000472	0.000162	7.47E-08	3.43E-05	6.89E-05	1.05E-05	6.92E-06	1.26E-05	0.0113
3.1.7		End of life		Landfill, wood		10	Pitch pine	1.38	oz	Estimate	0.0026	1.62E-06	1.32E-06	5.98E-06	3.67E-05	2.42E-08	1.09E-05	1.54E-05	2.23E-06	1.92E-06	3.50E-06	0.00255
4		Life cycle stage																				

CONCEPT 1

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints & canvases manufactured locally in Minneapolis

	Reference	
	Acrylic Painting on Canvas - baseline for 10 16x20 paintings	Locally Made Concept
	Reference	Image not provided
		5.5% performance improvement
Impacts per functional unit	1.8 mPts per 1 year of use	1.7 mPts per 1 year of use
Total amount of service delivered	10 x 1 year of use	10 x 1 year of use
Impacts of total service delivered	18 mPts	17 mPts
Assessment level	Estimate	Estimate
Greatest impacts		
SBOM input	Woven cotton fabric	Woven cotton fabric
Impact category	Carcinogenics	Carcinogenics
Life cycle stage	Manufacturing	Manufacturing
Total impacts by impact category		

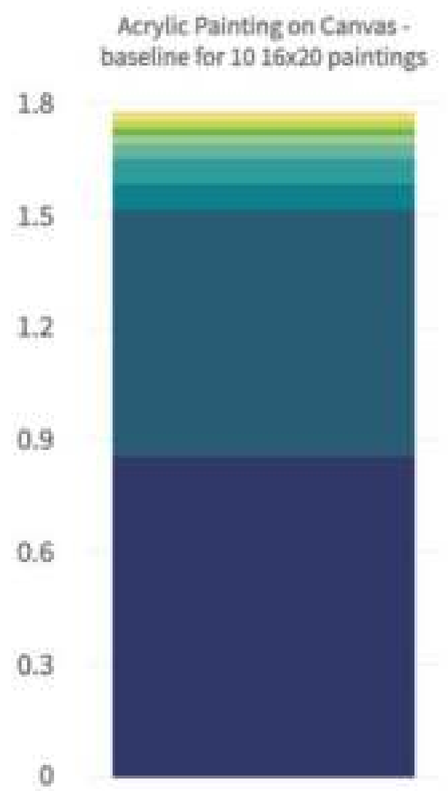


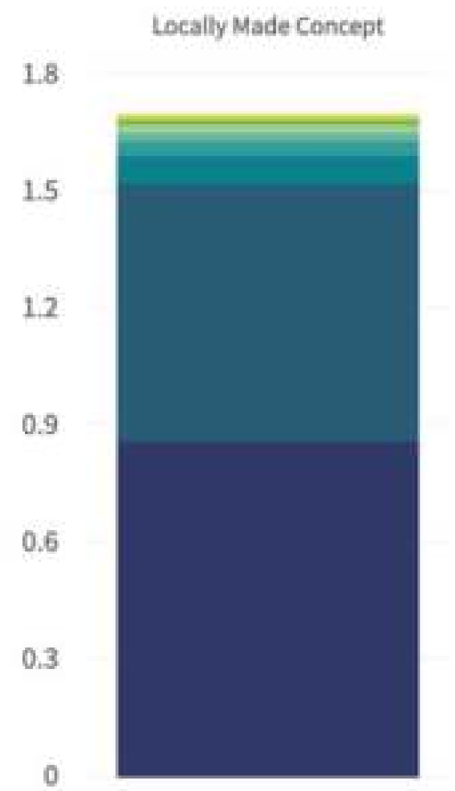
Impact category	%	Impact category	%
Ecological damage		**Ecological damage**	
Acidification	2.33	Acidification	2.19
Ecotoxicity	11.38	Ecotoxicity	11.86
Eutrophication	3.37	Eutrophication	3.39
Global warming	10.15	Global warming	9.58
Ozone depletion	0.01	Ozone depletion	0.01
Resource depletion		**Resource depletion**	
Fossil fuel depletion	4.18	Fossil fuel depletion	3.34
Human health damage		**Human health damage**	
Carcinogenics	58.22	Carcinogenics	59.75
Non carcinogenics	5.7	Non carcinogenics	5.75
Respiratory effects	2.62	Respiratory effects	2.56
Smog	2.04	Smog	1.57

CONCEPT 1

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints & canvases manufactured locally in Minneapolis.

Reference





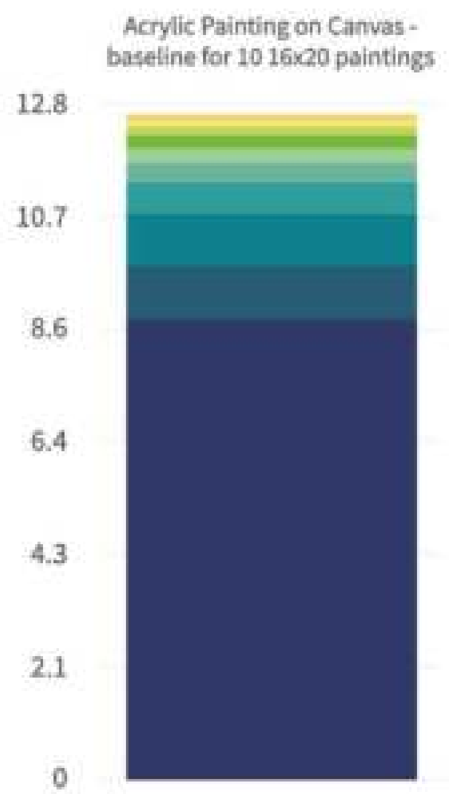
Total = 1.8mPts/func unit

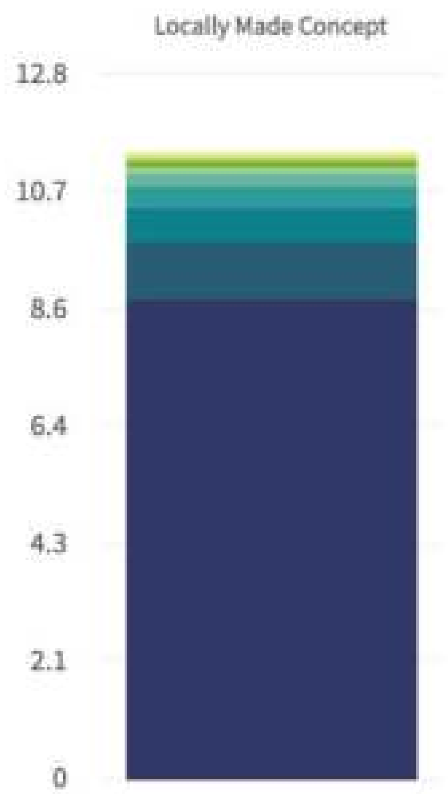
Input	mPts/func unit
Material - Woven cotton fabric	0.872
Material - Stainless steel, austenitic	0.666
Material - Titanium dioxide, production mix, inorganic	0.0710
Transportation - Truck, 20-28t	0.0685
Material - Acrylic binder, 34% in H2O	0.0385
Process - : Wire drawing, steel	0.0220
Material - Acrylic varnish, 87.5% in H2O	0.0218
Transportation - Truck, 20-28t	0.0206
Transportation - Freighter, oceanic	0.0110
Material - Acrylic varnish, 87.5% in H2O	0.0109

Total = 1.7mPts/func unit

Input	mPts/func unit
Material - Woven cotton fabric	0.872
Material - Stainless steel, austenitic	0.666
Material - Titanium dioxide, production mix, inorganic	0.0710
Material - Acrylic binder, 34% in H2O	0.0385
Process - : Wire drawing, steel	0.0220
Material - Acrylic varnish, 87.5% in H2O	0.0218
Material - Acrylic varnish, 87.5% in H2O	0.0109
Material - Carbon black	9.43x10⁻³
Material - Cadmium, primary	5.50x10⁻³
Process - : Wood, planing	2.11x10⁻³

Reference





Total = 13 CO2 eq. kg/func unit

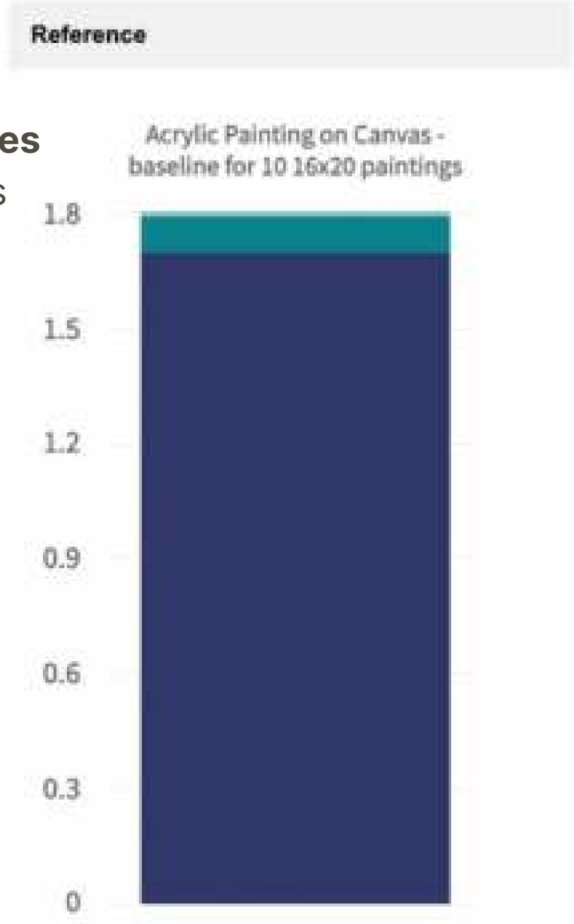
Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118

Total = 11 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Material - Acrylic varnish, 87.5% in H2O	0.236
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118
Material - Cadmium, primary	0.0668
Process - : Wire drawing, steel	0.0435
Process - : Wood, planing	0.0277

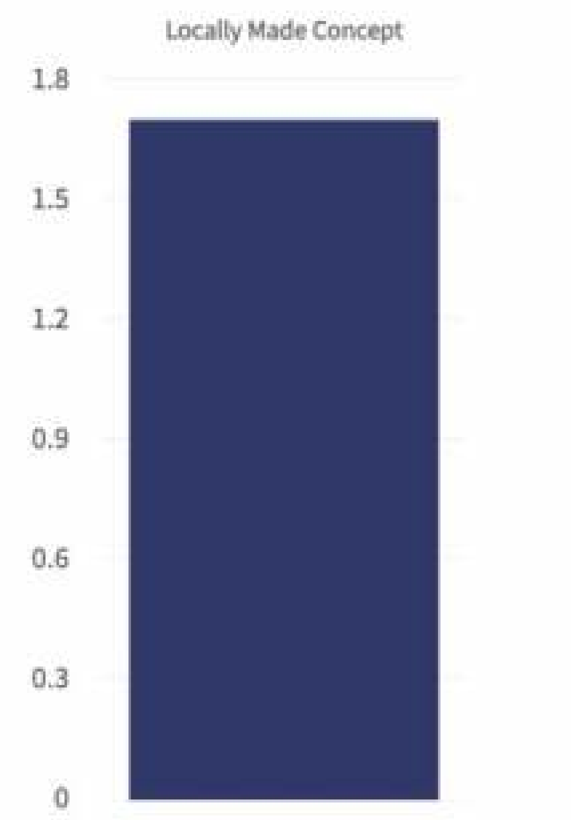
CONCEPT 1

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints & canvases manufactured locally in Minneapolis.



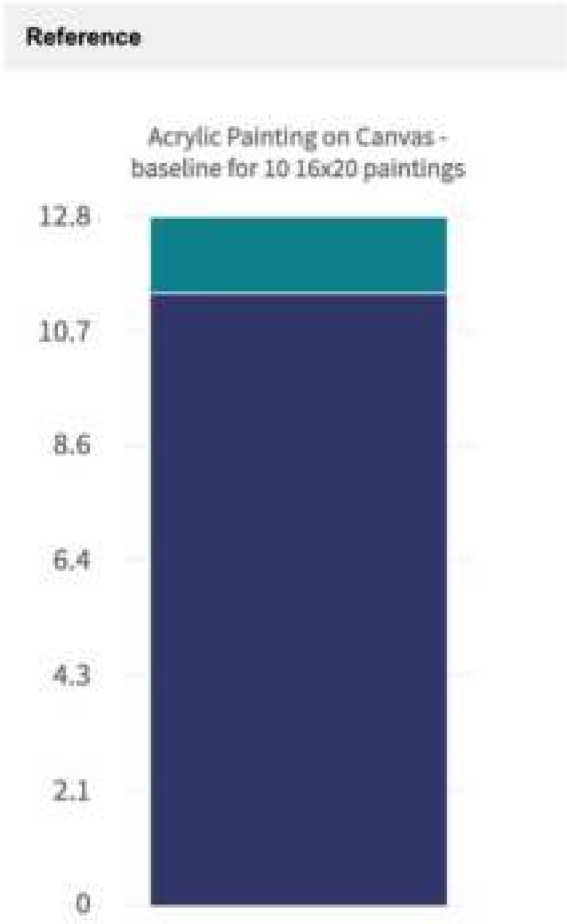
Total = 1.8mPts/func unit

	Lifecycle stage	mPts/func unit
	Manufacturing	1.72
	End of life	1.51×10^{-3}
	Transportation	0.100
	Use	2.54×10^{-4}



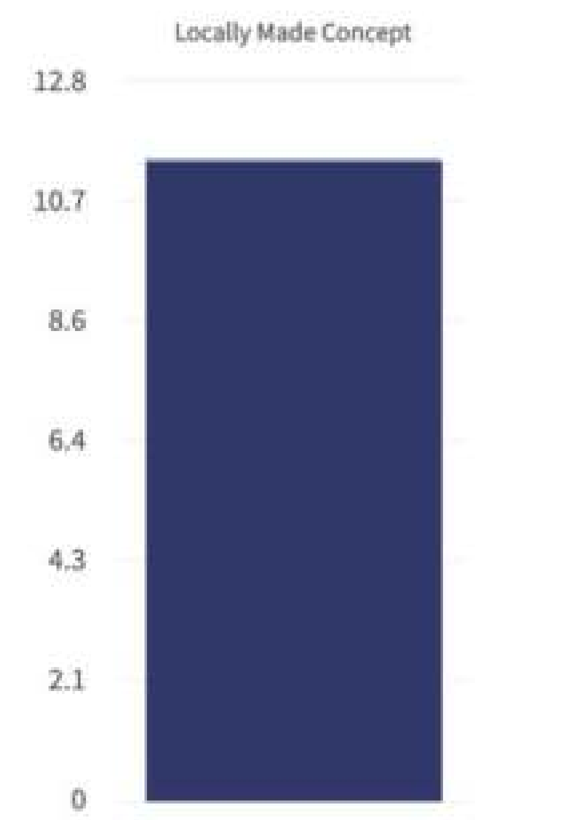
Total = 1.7mPts/func unit

	Lifecycle stage	mPts/func unit
	Manufacturing	1.72
	End of life	1.51x10⁻³
	Use	2.54x10⁻⁴



Total = 13 CO2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Manufacturing	11.4
	End of life	0.0233
	Transportation	1.38
	Use	3.29×10^{-3}



Total = 11 CO2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Manufacturing	11.4
	End of life	0.0233
	Use	3.29x10⁻³

CONCEPT 2

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints on wooden substrate.

Project:	Acrylic Painting
Concept:	Acrylic Painting on Wood
Methodology	SM 2013
Date:	
Created by:	
Total Amoun	10 x 1 year of use

Item	Row type	Name	Description	Qty	Material/pro	Amount	Units	Measuremer	Total (mp	Acidification	Ecotoxicity (r	Eutrophicatic	Global warm	Ozone deple	Fossil fuel de	Carcinogenic	Non carcinog	Respiratory	Smog (mpts)	CO2 Equivalent (kgs)
0	concept	Acrylic Painting on Wood							0.218	0.00829	0.00812	0.005	0.0411	8.62E-05	0.0426	0.0787	0.0126	0.00737	0.014	2.85
1	Life cycle stage																			
1.1	Part	Beech Panel	cradled beec	10		29	oz													
1.1.1	Material	Beech Panel as Substrate			Beech timbe	29	oz	Estimate	0.104	0.000201	0.000551	0.000242	0.00141	3.31E-06	0.0013	0.00169	0.000247	0.000238	0.000441	0.0976
1.2	Part	Pigment - Ti	Placeholder f	10		4	oz													
1.2.1	Material	Pigment - TiO2			Titanium dio	4	oz	Estimate	0.557	0.00153	0.00149	0.000457	0.00752	1.51E-05	0.00691	0.0112	0.00351	0.00162	0.00123	0.522
1.3	Part	Pigment - Ca	Placeholder f	10		2	oz													
1.3.1	Material	Pigment - Carbon Black			Carbon black	2	oz	Estimate	0.146	0.000154	0.000178	4.81E-05	0.00197	1.47E-05	0.00475	0.00152	0.000236	0.000388	0.000175	0.137
1.4	Part	Acrylic Varnish to Seal		10		2	oz													
1.4.1	Material	Acrylic Varnish to Seal			Acrylic varnis	2	oz	Estimate	0.129	0.000237	0.000525	0.000259	0.0017	2.66E-06	0.00174	0.00511	0.000864	0.000229	0.000221	0.118
1.5	Part	Acrylic Binde	Estimate 4 t	10		8	oz													
1.5.1	Material	Acrylic Binder to bind pigments			Acrylic binde	8	oz	Estimate	0.401	0.000656	0.00155	0.000419	0.00523	5.09E-06	0.00704	0.0205	0.00185	0.000642	0.000569	0.363
1.6	Part	Pigment - Cadmium		10		2	oz													
1.6.1	Material	Pigment - Cadmium			Cadmium, pr	2	oz	Estimate	0.0723	0.00019	0.000261	3.50E-05	0.000964	5.24E-07	0.0003	0.00298	0.000486	0.000157	0.000123	0.0668
2	Life cycle stage																			
2.1	Water use	Water			Tap water, a	20	gal	Estimate	0.00355	8.18E-06	1.30E-05	1.61E-06	4.75E-05	2.43E-08	1.38E-05	0.000136	2.14E-05	6.90E-06	5.86E-06	0.00329
3	Life cycle stage																			
3.1.2	End of life	Landfill, sanitary, generic		10	Titanium dio	4	oz	Estimate	0.00067	2.25E-06	7.73E-07	1.58E-06	9.05E-06	1.33E-08	7.30E-06	8.38E-06	1.29E-06	3.05E-06	5.12E-06	0.000628
3.1.4	End of life	Landfill, polyurethane		10	Acrylic varnis	2	oz	Estimate	0.00602	3.69E-06	5.64E-06	0.000236	8.12E-05	3.74E-08	1.71E-05	3.44E-05	5.23E-06	3.46E-06	6.28E-06	0.00563
4	Life cycle stage																			
4.1	Transportation - Assembled product																			
4.1.1	Transportation - Assembled product			1	Freighter, oc	11350	km	Estimate	0.187	0.00148	0.000229	0.000529	0.00252	3.65E-06	0.00202	0.00214	0.000394	0.00101	0.00188	0.175
4.1.2	Transportation - Assembled product			1	Truck, 20-28t	3800	km	Estimate	1.12	0.00294	0.00256	0.00213	0.0151	3.17E-05	0.0142	0.0256	0.00383	0.00236	0.00723	1.05
4.1.3	Transportation - Assembled product			1	Truck, 20-28t	1140	km	Estimate	0.337	0.000883	0.000767	0.00064	0.00453	9.50E-06	0.00427	0.00768	0.00115	0.000707	0.00217	0.314

CONCEPT 2

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints on wooden substrate.

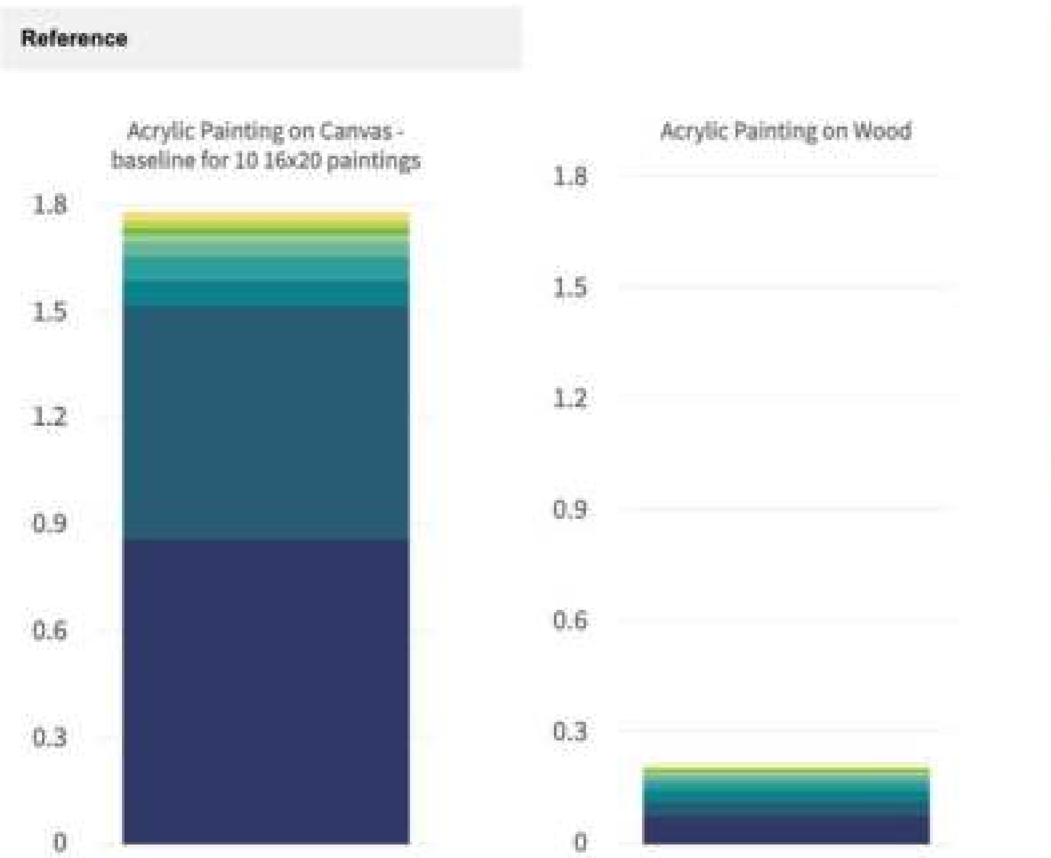
	Reference	
	Acrylic Painting on Canvas - baseline for 10 16x20 paintings	Acrylic Painting on Wood
	Reference	Image not provided
		88% performance improvement
Impacts per functional unit	1.8 mPts per 1 year of use	0.22 mPts per 1 year of use
Total amount of service delivered	10 x 1 year of use	10 x 1 year of use
Impacts of total service delivered	18 mPts	2.2 mPts
Assessment level	Estimate	Estimate
Greatest impacts		
SBOM input	Woven cotton fabric	Truck, 20-28t
Impact category	Carcinogenics	Carcinogenics
Life cycle stage	Manufacturing	Transportation

Total impacts by impact category

Impact category	%	Impact category	%
Ecological damage		**Ecological damage**	
Acidification	2.33	Acidification	3.81
Ecotoxicity	11.38	Ecotoxicity	3.73
Eutrophication	3.37	Eutrophication	2.3
Global warming	10.15	Global warming	18.85
Ozone depletion	0.01	Ozone depletion	0.04
Resource depletion		**Resource depletion**	
Fossil fuel depletion	4.18	Fossil fuel depletion	19.55
Human health damage		**Human health damage**	
Carcinogenics	58.22	Carcinogenics	36.12
Non carcinogenics	5.7	Non carcinogenics	5.78
Respiratory effects	2.62	Respiratory effects	3.38
Smog	2.04	Smog	6.45

CONCEPT 2

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints on wooden substrate.

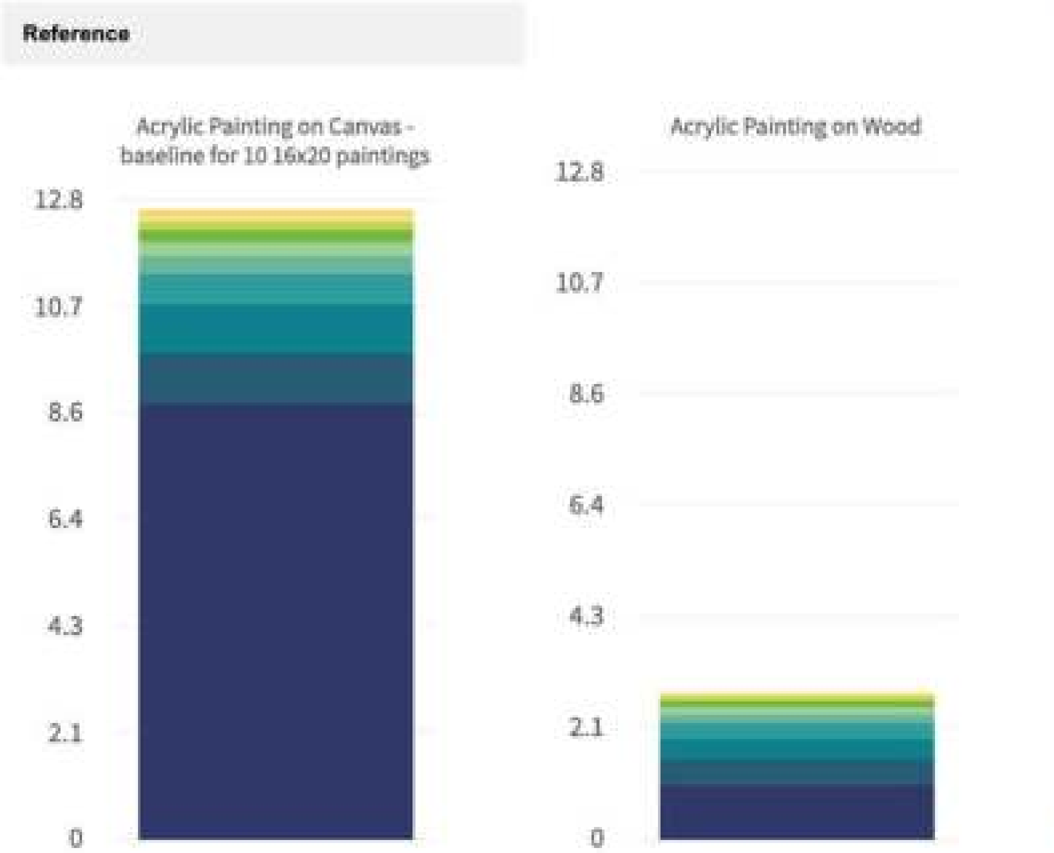


Total = 1.8mPts/func unit

Input	mPts/func unit
Material - Woven cotton fabric	0.872
Material - Stainless steel, austenitic	0.666
Material - Titanium dioxide, production mix, inorganic	0.0710
Transportation - Truck, 20-28t	0.0685
Material - Acrylic binder, 34% in H2O	0.0385
Process - : Wire drawing, steel	0.0220
Material - Acrylic varnish, 87.5% in H2O	0.0218
Transportation - Truck, 20-28t	0.0206
Transportation - Freighter, oceanic	0.0110
Material - Acrylic varnish, 87.5% in H2O	0.0109

Total = 0.22mPts/func unit

Input	mPts/func unit
Transportation - Truck, 20-28t	0.0760
Material - Acrylic binder, 34% in H2O	0.0385
Material - Titanium dioxide, production mix, inorganic	0.0355
Transportation - Truck, 20-28t	0.0228
Transportation - Freighter, oceanic	0.0122
Material - Acrylic varnish, 87.5% in H2O	0.0109
Material - Carbon black	9.43x10⁻³
Material - Beech timber	6.33x10⁻³
Material - Cadmium, primary	5.50x10⁻³
EOL - : Landfill, polyurethane	3.93x10⁻⁴



Total = 13 CO2 eq. kg/func unit

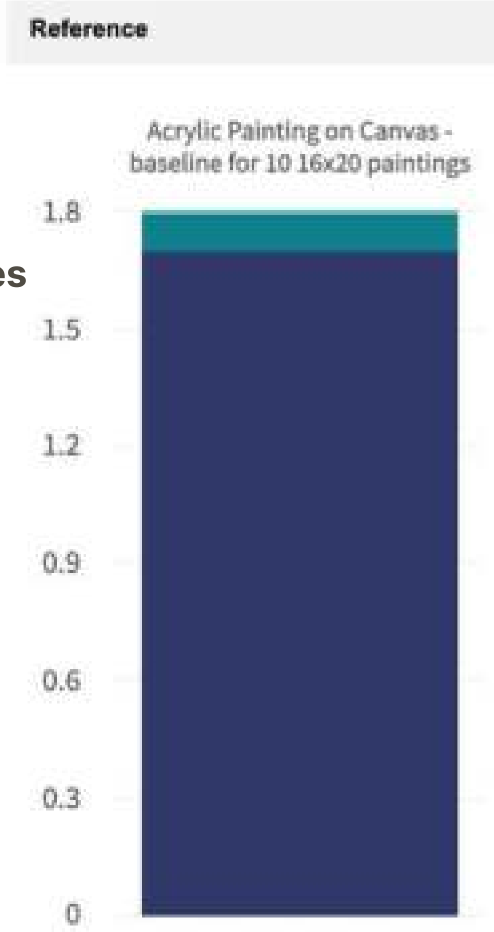
Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118

Total = 2.8 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Transportation - Truck, 20-28t	1.05
Material - Titanium dioxide, production mix, inorganic	0.522
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.314
Transportation - Freighter, oceanic	0.175
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118
Material - Beech timber	0.0976
Material - Cadmium, primary	0.0668
EOL - : Landfill, polyurethane	5.63x10⁻³

CONCEPT 2

Acrylic Painting - 10 paintings, size 16x20 inches
Commercially available acrylic paints on wooden substrate.

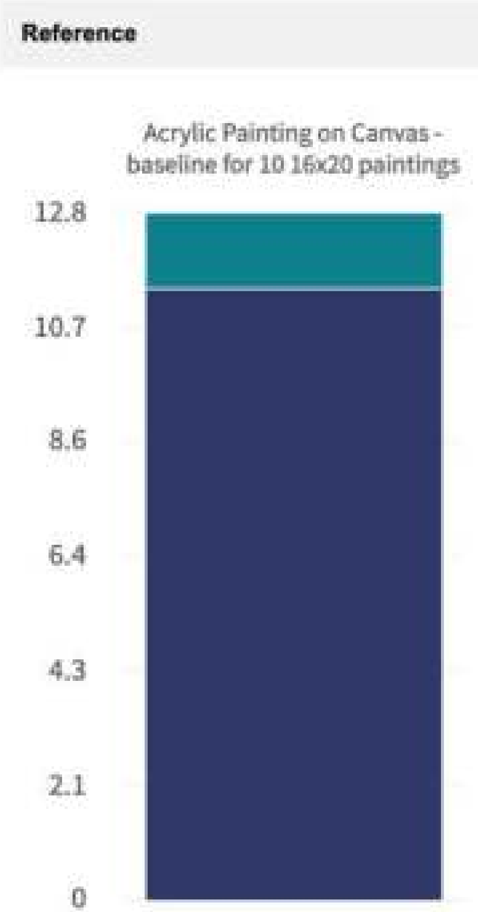


Total = 1.8mPts/func unit

	Lifecycle stage	mPts/func unit
	Manufacturing	1.72
	End of life	$1.51x10^{-3}$
	Transportation	0.100
	Use	$2.54x10^{-4}$

Total = 0.22mPts/func unit

	Lifecycle stage	mPts/func unit
	Manufacturing	0.106
	End of life	4.32x10⁻⁴
	Transportation	0.111
	Use	2.54x10⁻⁴



Total = 13 CO2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Manufacturing	11.4
	End of life	0.0233
	Transportation	1.38
	Use	$3.29x10^{-3}$

Total = 2.8 CO2 eq. kg/func unit

	Lifecycle stage	CO2 eq. kg/func unit
	Manufacturing	1.30
	End of life	6.26x10⁻³
	Transportation	1.54
	Use	3.29x10⁻³

Appendix D/System Bill of Materials (SBOM)

CONCEPT 3

Acrylic Painting - 10 paintings, size 16x20 inches

Foraged Pigments w/Acrylic Binders on commercial canvases

Project:	Acrylic Painting
Concept:	DIY foraged pigments using acrylic binders and commercial canvas
Methodolog	SM 2013
Date:	#
Created by:	
Total Amour	10 x 1 year of use

Item	St	Row type	Pa	Name	Description	Qty	Material/pro	Amount	Units	Measuremer	Total (mpts)	Acidification	Ecotoxicity (r	Eutrophicatic	Global warm	Ozone deple	Fossil fuel de	Carcinogenic	Non carcinog	Respiratory	Smog (mpts)	CO2 Equivalent (kgs)
0		concept		DIY foraged pigments using acrylic binders and commercial canvas							1.75	0.0398	0.205	0.0603	0.171	9.89E-05	0.0606	1.04	0.0987	0.0449	0.0338	11.8
1		Life cycle stage																				
1.1		Part		Staples		400		0.1	oz													
1.1.1		Material proce:		Process			Wire drawin	0.1	oz	Estimate	0.0655	6.94E-05	0.000848	2.74E-05	0.000627	5.89E-07	0.000189	0.0198	0.000309	8.99E-05	5.64E-05	0.0435
1.1.2		Material		Staples			Stainless ste	0.1	oz	Estimate	1.29	0.0016	0.0268	0.000355	0.00895	5.56E-06	0.00341	0.59	0.0281	0.00612	0.00131	0.621
1.2		Part		Canvas	Not indicate	10		11	oz													
1.2.1		Material		Canvas			Woven cotto	11	oz	Estimate	9.63	0.0311	0.17	0.0551	0.126	3.13E-05	0.0225	0.355	0.058	0.0326	0.0214	8.75
1.3		Part		Pigment - Ti	gesso only	10		4	oz													
1.3.1		Material		Pigment - TiO2			Titanium dio	4	oz	Estimate	0.557	0.00153	0.00149	0.000457	0.00752	1.51E-05	0.00691	0.0112	0.00351	0.00162	0.00123	0.522
1.4		Part		Acrylic Varnish to Seal		10		2	oz													
1.4.1		Material		Acrylic Varnish to Seal			Acrylic varnis	2	oz	Estimate	0.129	0.000237	0.000525	0.000259	0.0017	2.66E-06	0.00174	0.00511	0.000864	0.000229	0.000221	0.118
1.5		Part		Acrylic Gesso (Base Coat)		10		4	oz													
1.5.1		Material		Acrylic Gesso (Base Coat)			Acrylic varnis	4	oz	Estimate	0.258	0.000474	0.00105	0.000519	0.0034	5.32E-06	0.00349	0.0102	0.00173	0.000459	0.000442	0.236
1.6		Part		Stretcher Ba	Medium wei	10		1.38	oz													
1.6.1		Material proce:		Process			Wood, planir	1.38	lbs	Estimate	0.0298	7.62E-05	9.30E-05	1.59E-05	0.000399	2.07E-07	0.000123	0.00107	0.000219	6.37E-05	4.94E-05	0.0277
1.6.2		Material		Stretcher Bars			Pitch pine	1.38	oz	Estimate	0.0132	6.81E-05	0.00024	3.10E-05	0.000171	3.32E-08	0.000161	0.00033	9.66E-05	1.43E-05	0.000166	0.0119
1.7		Part		Acrylic Binde	Estimate 4 t	10		8	oz													
1.7.1		Material		Acrylic Binder to bind pigments			Acrylic binde	8	oz	Estimate	0.401	0.000656	0.00155	0.000419	0.00523	5.09E-06	0.00704	0.0205	0.00185	0.000642	0.000569	0.363
2		Life cycle stage																				
2.1		Water use		Water			Tap water, a	20	gal	Estimate	0.00355	8.18E-06	1.30E-05	1.61E-06	4.75E-05	2.43E-08	1.38E-05	0.000136	2.14E-05	6.90E-06	5.86E-06	0.00329
3		Life cycle stage																				
3.1.1		End of life		Landfill, steel		400	Stainless ste	0.1	oz	Estimate	0.000929	2.58E-06	1.63E-06	1.93E-06	1.24E-05	4.80E-08	2.02E-05	1.66E-05	2.53E-06	2.98E-06	6.07E-06	0.000862
3.1.2		End of life		Landfill, sanitary, generic		10	Woven cotto	11	oz	Estimate	0.00183	6.19E-06	2.12E-06	4.35E-06	2.49E-05	3.64E-08	2.01E-05	2.30E-05	3.55E-06	8.39E-06	1.41E-05	0.00173
3.1.3		End of life		Landfill, sanitary, generic		10	Titanium dio	4	oz	Estimate	0.000666	2.25E-06	7.73E-07	1.58E-06	9.05E-06	1.33E-08	7.30E-06	8.38E-06	1.29E-06	3.05E-06	5.12E-06	0.000628
3.1.4		End of life		Landfill, polyurethane		10	Acrylic varnis	2	oz	Estimate	0.00602	3.69E-06	5.64E-06	0.000236	8.12E-05	3.74E-08	1.71E-05	3.44E-05	5.23E-06	3.46E-06	6.28E-06	0.00563
3.1.5		End of life		Landfill, polyurethane		10	Acrylic varnis	4	oz	Estimate	0.012	7.38E-06	1.13E-05	0.000472	0.000162	7.47E-08	3.43E-05	6.89E-05	1.05E-05	6.92E-06	1.26E-05	0.0113
3.1.6		End of life		Landfill, wood		10	Pitch pine	1.38	oz	Estimate	0.00263	1.62E-06	1.32E-06	5.98E-06	3.67E-05	2.42E-08	1.09E-05	1.54E-05	2.23E-06	1.92E-06	3.50E-06	0.00255
4		Life cycle stage																				
4.1		Transportation - Assembled product																				
4.1.1		Transportation - Assembled product				1	Freighter, oc	11350	km	Estimate	0.137	0.00108	0.000168	0.000387	0.00184	2.67E-06	0.00148	0.00157	0.000288	0.00074	0.00137	0.128
4.1.2		Transportation - Assembled product				1	Truck, 20-28t	3800	km	Estimate	0.821	0.00215	0.00187	0.00156	0.011	2.32E-05	0.0104	0.0187	0.0028	0.00172	0.00529	0.766
4.1.3		Transportation - Assembled product				1	Truck, 20-28t	1140	km	Estimate	0.246	0.000646	0.000561	0.000468	0.00331	6.95E-06	0.00312	0.00562	0.000839	0.000517	0.00159	0.23

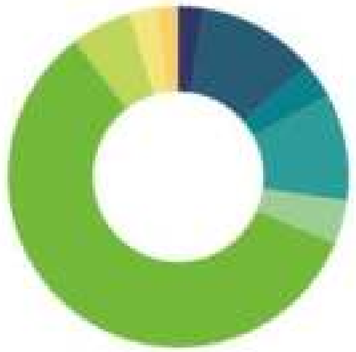
CONCEPT 3

Acrylic Painting - 10 paintings, size 16x20 inches
Foraged Pigments w/Acrylic Binders on commercial canvases

Reference	
Acrylic Painting on Canvas - baseline for 10 16x20 paintings	DIY foraged pigments using acrylic binders and commercial canvas
Reference	Image not provided
	3.8% performance improvement

	Reference	DIY foraged pigments
Impacts per functional unit	1.8 mPts per 1 year of use	1.8 mPts per 1 year of use
Total amount of service delivered	10 x 1 year of use	10 x 1 year of use
Impacts of total service delivered	18 mPts	18 mPts
Assessment level	Estimate	Estimate
Greatest impacts		
SBOM input	Woven cotton fabric	Woven cotton fabric
Impact category	Carcinogenics	Carcinogenics
Life cycle stage	Manufacturing	Manufacturing

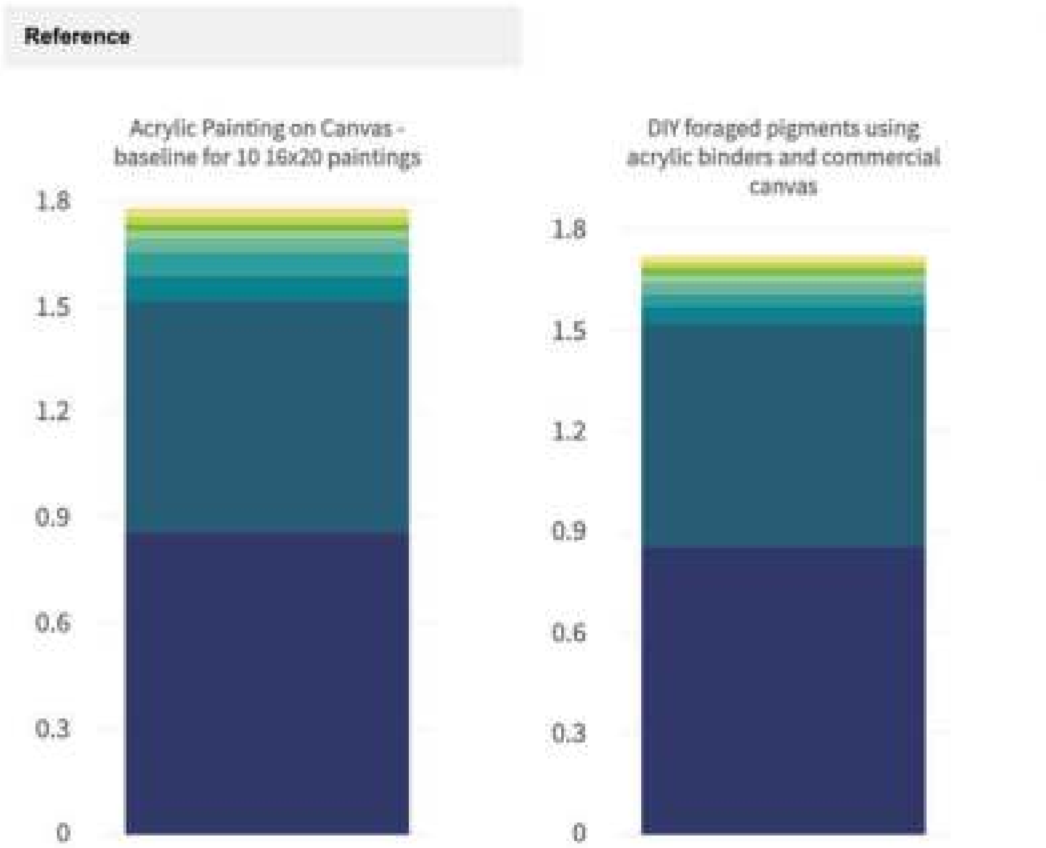
Total impacts by impact category




Impact category	%	Impact category	%
Ecological damage		**Ecological damage**	
Acidification	2.33	Acidification	2.27
Ecotoxicity	11.38	Ecotoxicity	11.69
Eutrophication	3.37	Eutrophication	3.44
Global warming	10.15	Global warming	9.74
Ozone depletion	0.01	Ozone depletion	0.01
Resource depletion		**Resource depletion**	
Fossil fuel depletion	4.18	Fossil fuel depletion	3.46
Human health damage		**Human health damage**	
Carcinogenics	58.22	Carcinogenics	59.28
Non carcinogenics	5.7	Non carcinogenics	5.63
Respiratory effects	2.62	Respiratory effects	2.56
Smog	2.04	Smog	1.93

CONCEPT 3

Acrylic Painting - 10 paintings, size 16x20 inches
Foraged Pigments w/Acrylic Binders on commercial canvases

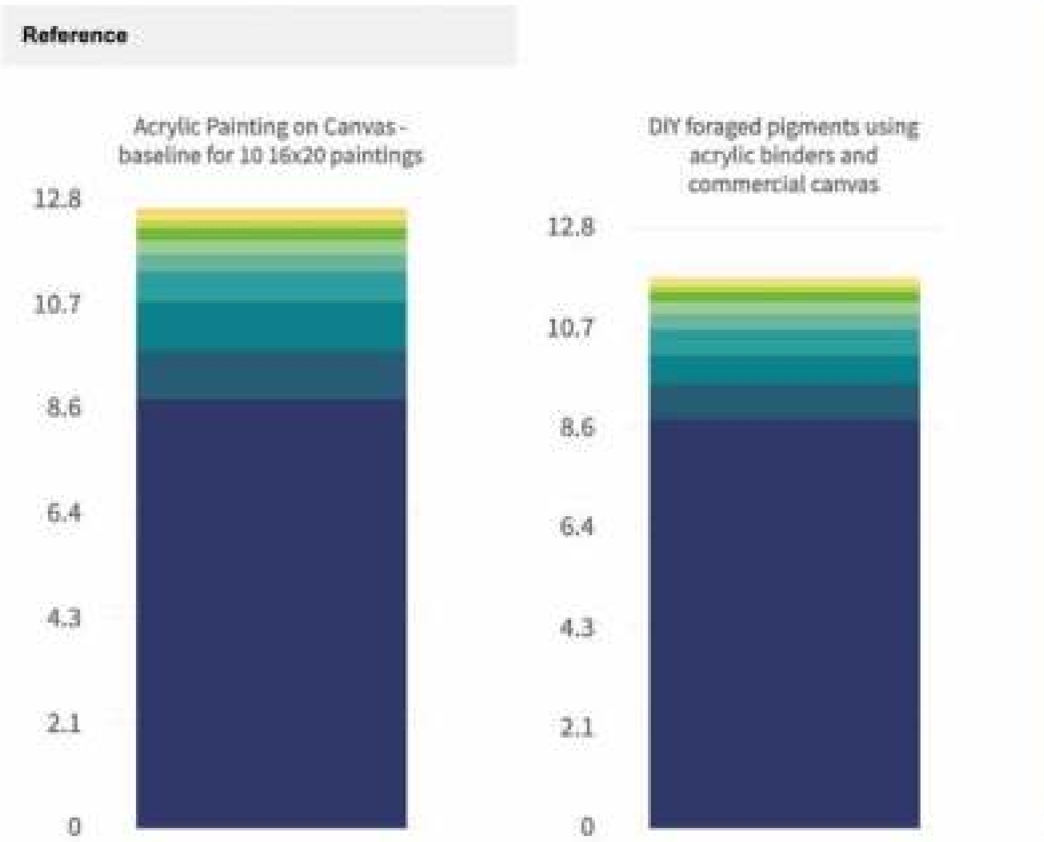


Total = 1.8mPts/func unit

Input	mPts/func unit
Material - Woven cotton fabric	0.872
Material - Stainless steel, austenitic	0.666
Material - Titanium dioxide, production mix, inorganic	0.0710
Transportation - Truck, 20-28t	0.0685
Material - Acrylic binder, 34% in H2O	0.0385
Process - : Wire drawing, steel	0.0220
Material - Acrylic varnish, 87.5% in H2O	0.0218
Transportation - Truck, 20-28t	0.0206
Transportation - Freighter, oceanic	0.0110
Material - Acrylic varnish, 87.5% in H2O	0.0109

Total = 1.8mPts/func unit

Input	mPts/func unit
Material - Woven cotton fabric	0.872
Material - Stainless steel, austenitic	0.666
Transportation - Truck, 20-28t	0.0556
Material - Acrylic binder, 34% in H2O	0.0385
Material - Titanium dioxide, production mix, inorganic	0.0355
Process - : Wire drawing, steel	0.0220
Material - Acrylic varnish, 87.5% in H2O	0.0218
Transportation - Truck, 20-28t	0.0167
Material - Acrylic varnish, 87.5% in H2O	0.0109
Transportation - Freighter, oceanic	8.93x10⁻³



Total = 13 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118

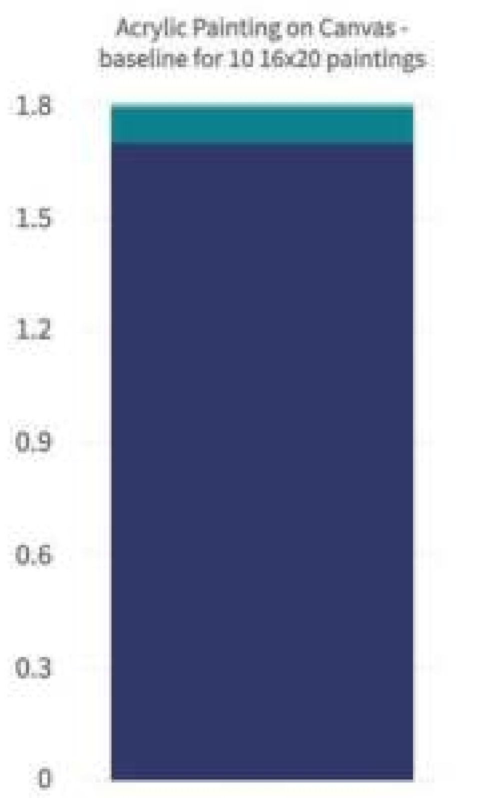
Total = 12 CO2 eq. kg/func unit

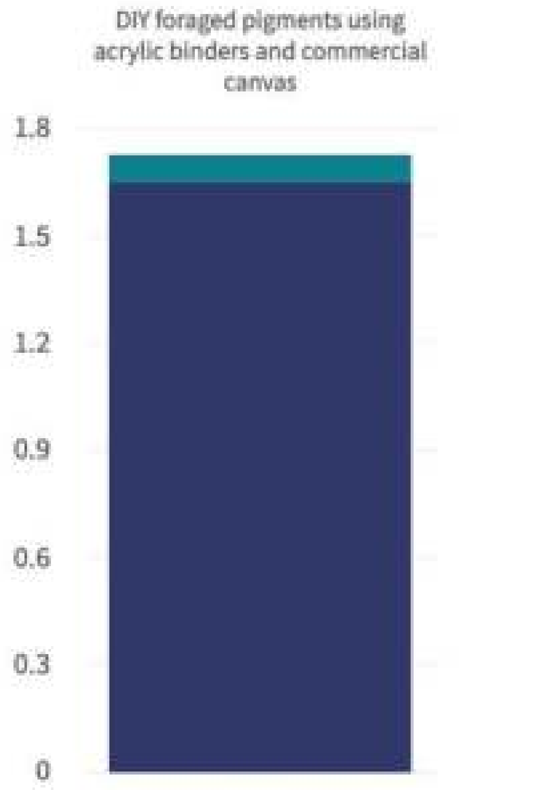
Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Transportation - Truck, 20-28t	0.766
Material - Stainless steel, austenitic	0.621
Material - Titanium dioxide, production mix, inorganic	0.522
Material - Acrylic binder, 34% in H2O	0.363
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Truck, 20-28t	0.230
Transportation - Freighter, oceanic	0.128
Material - Acrylic varnish, 87.5% in H2O	0.118
Process - : Wire drawing, steel	0.0435

CONCEPT 3

Acrylic Painting - 10 paintings, size 16x20 inches
Foraged Pigments w/Acrylic Binders on commercial canvases

Reference





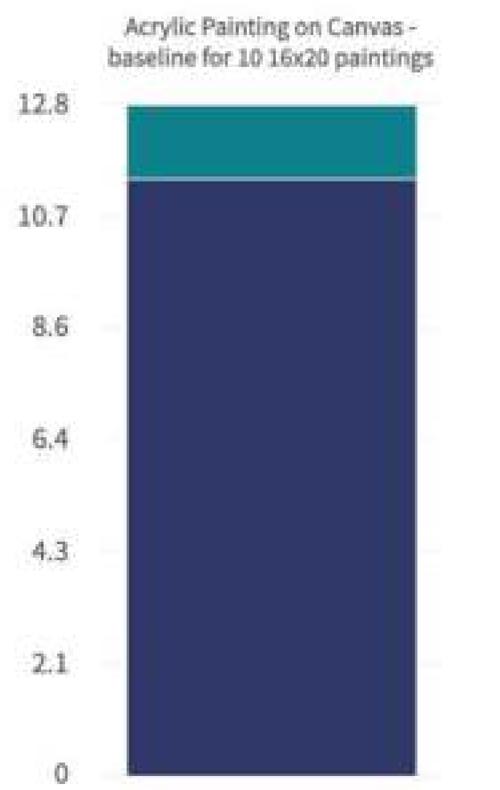
Total = 1.8mPts/func unit

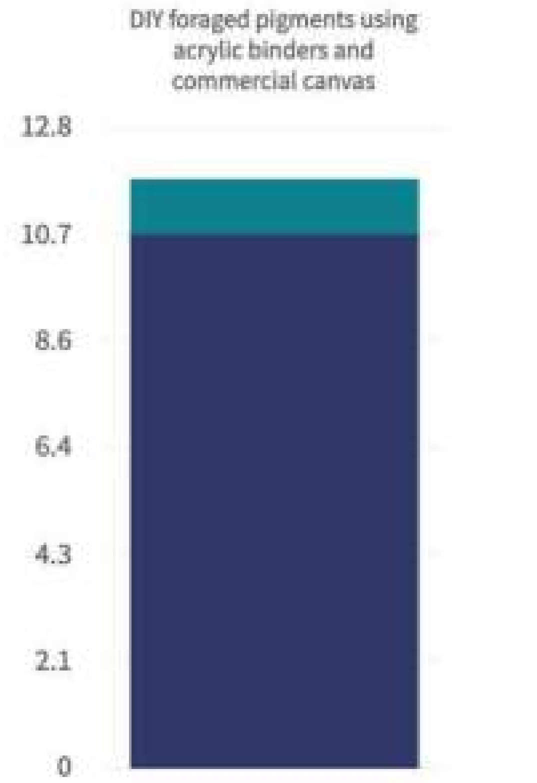
Lifecycle stage	mPts/func unit
Manufacturing	1.72
End of life	$1.51x10^{-3}$
Transportation	0.100
Use	$2.54x10^{-4}$

Total = 1.8mPts/func unit

Lifecycle stage	mPts/func unit
Manufacturing	1.67
End of life	1.47x10⁻³
Transportation	0.0812
Use	2.54x10⁻⁴

Reference





Total = 13 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Manufacturing	11.4
End of life	0.0233
Transportation	1.38
Use	$3.29x10^{-3}$

Total = 12 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Manufacturing	10.7
End of life	0.0227
Transportation	1.12
Use	3.29x10⁻³

CONCEPT 4

Acrylic Painting - 10 paintings, size 16x20 inches
Handmade recycled paper with foraged inks or watercolors

Project:	Acrylic Painting																					
Concept:	Handmade recycled paper with foraged inks or watercolors																					
Methodology	SM 2013																					
Date:	#																					
Created by:																						
Total Amoun	10 x 1 year of use																					
Item	St	Row type	Part ID	Name	Descri	Qty	Material/prc	Amount	Units	Measuremer	Total (mpts)	Acidification	Ecotoxicity (r	Eutrophicatic	Global warm	Ozone deple	Fossil fuel d	Carcinogenic	Non carcinog	Respiratory (	Smog (mpts]	CO2 Equivalent (kgs)
0		concept		Handmade recycled paper with foraged inks or watercolors							0.000254	8.18E-06	1.30E-05	1.61E-06	4.75E-05	2.43E-08	1.38E-05	0.000136	2.14E-05	6.90E-06	5.86E-06	0.00329
1		Life cycle stage																				
2		Life cycle stage																				
2.1		Water use		Water			Tap water, a	20	gal	Estimate	0.00355	8.18E-06	1.30E-05	1.61E-06	4.75E-05	2.43E-08	1.38E-05	0.000136	2.14E-05	6.90E-06	5.86E-06	0.00329
3		Life cycle stage																				
4		Life cycle stage																				
4.1		Transportation - Assembled product																				
4.1.1		Transportation - Assembled product				1	Van, <3.5t	25	km	Estimate	0	0	0	0	0	0	0	0	0	0	0	0

CONCEPT 4

Acrylic Painting - 10 paintings, size 16x20 inches
Handmade recycled paper with foraged inks or watercolors

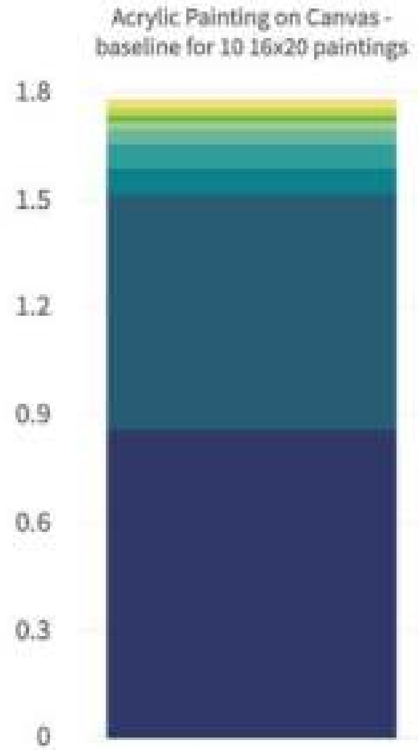
	Reference	
	Acrylic Painting on Canvas - baseline for 10 16x20 paintings	Handmade recycled paper with foraged inks or watercolors
	Reference	Image not provided
		100% performance improvement
Impacts per functional unit	1.8 mPts per 1 year of use	$2.5x10^{-4}$ mPts per 1 year of use
Total amount of service delivered	10 x 1 year of use	10 x 1 year of use
Impacts of total service delivered	18 mPts	$2.5x10^{-3}$ mPts
Assessment level	Estimate	Estimate
Greatest impacts		
SBOM input	Woven cotton fabric	Tap water, at user
Impact category	Carcinogenics	Carcinogenics
Life cycle stage	Manufacturing	Use
Total impacts by impact category		


Impact category	%	Impact category	%
Ecological damage		**Ecological damage**	
Acidification	2.33	Acidification	3.22
Ecotoxicity	11.38	Ecotoxicity	5.11
Eutrophication	3.37	Eutrophication	0.63
Global warming	10.15	Global warming	18.71
Ozone depletion	0.01	Ozone depletion	0.01
Resource depletion		**Resource depletion**	
Fossil fuel depletion	4.18	Fossil fuel depletion	5.43
Human health damage		**Human health damage**	
Carcinogenics	58.22	Carcinogenics	53.44
Non carcinogenics	5.7	Non carcinogenics	8.42
Respiratory effects	2.62	Respiratory effects	2.72
Smog	2.04	Smog	2.31

CONCEPT 4

Acrylic Painting - 10 paintings, size 16x20 inches
Handmade recycled paper with foraged inks or watercolors

Reference



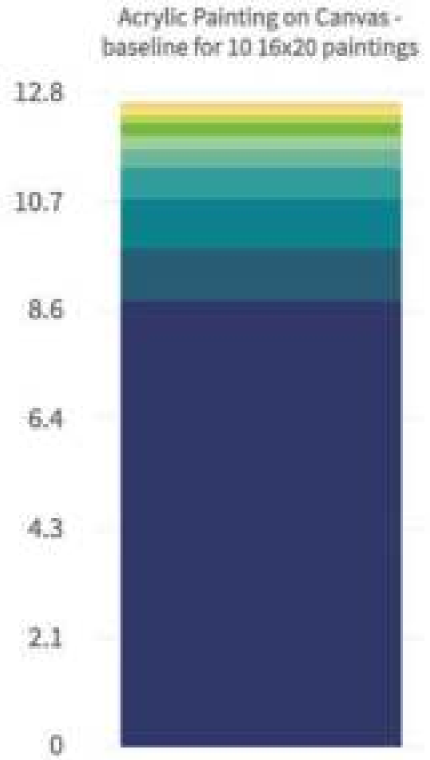
Total = 1.8mPts/func unit

Input	mPts/func unit
Material - Woven cotton fabric	0.872
Material - Stainless steel, austenitic	0.666
Material - Titanium dioxide, production mix, inorganic	0.0710
Transportation - Truck, 20-28t	0.0685
Material - Acrylic binder, 34% in H2O	0.0385
Process - : Wire drawing, steel	0.0220
Material - Acrylic varnish, 87.5% in H2O	0.0218
Transportation - Truck, 20-28t	0.0206
Transportation - Freighter, oceanic	0.0110
Material - Acrylic varnish, 87.5% in H2O	0.0109

Total = 2.5x10-4 mPts/func unit

Input	mPts/func unit
Use - Tap water, at user	2.54x10⁻⁴
Transportation - Van, <3.5t	0

Reference



Total = 13 CO2 eq. kg/func unit

Input	CO2 eq. kg/func unit
Material - Woven cotton fabric	8.75
Material - Titanium dioxide, production mix, inorganic	1.04
Transportation - Truck, 20-28t	0.944
Material - Stainless steel, austenitic	0.621
Material - Acrylic binder, 34% in H2O	0.363
Transportation - Truck, 20-28t	0.283
Material - Acrylic varnish, 87.5% in H2O	0.236
Transportation - Freighter, oceanic	0.157
Material - Carbon black	0.137
Material - Acrylic varnish, 87.5% in H2O	0.118

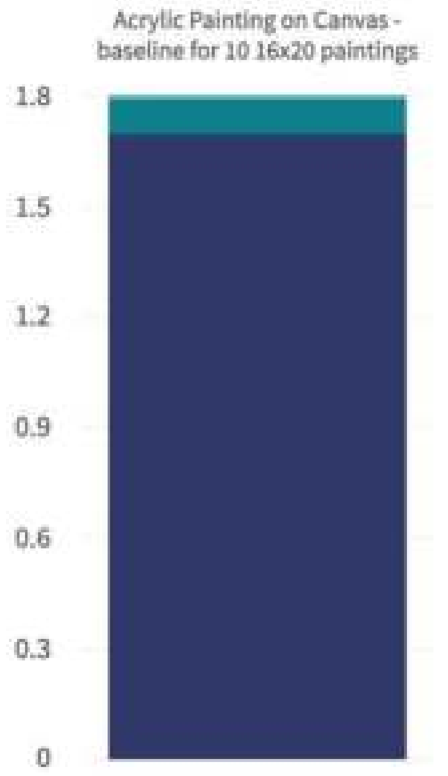
Total = 3.3x10-3 CO2 eq. kg/func unit

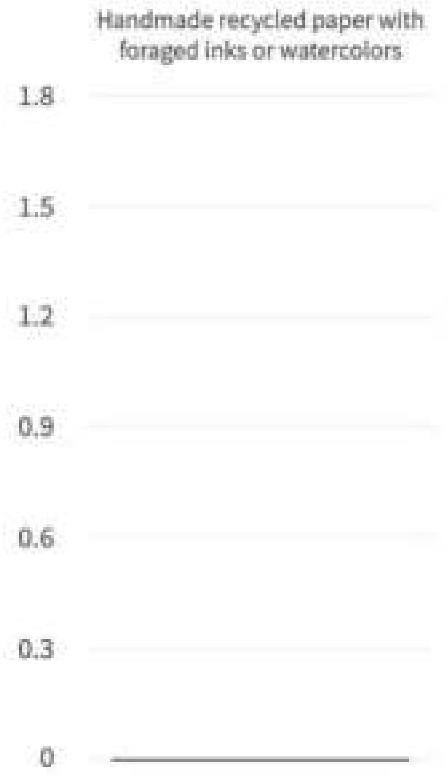
Input	CO2 eq. kg/func unit
Use - Tap water, at user	3.29x10⁻³
Transportation - Van, <3.5t	0

CONCEPT 4

Acrylic Painting - 10 paintings, size 16x20 inches
Handmade recycled paper with foraged inks or watercolors

Reference





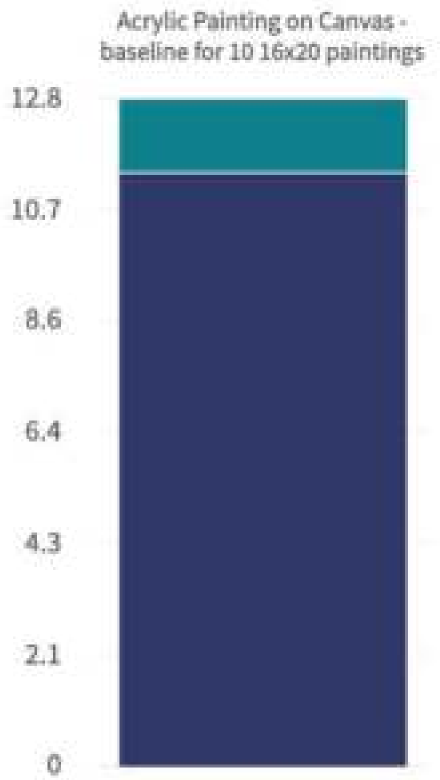
Total = 1.8mPts/func unit

Lifecycle stage	mPts/func unit
Manufacturing	1.72
End of life	$1.51x10^{-3}$
Transportation	0.100
Use	$2.54x10^{-4}$

Total = 2.5x10-4 mPts/func unit

Lifecycle stage	mPts/func unit
Transportation	0
Use	2.54x10⁻⁴

Reference



Total = 13 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Manufacturing	11.4
End of life	0.0233
Transportation	1.38
Use	$3.29x10^{-3}$

Total = 3.3x10-3 CO2 eq. kg/func unit

Lifecycle stage	CO2 eq. kg/func unit
Transportation	0
Use	3.29x10⁻³