**Introduction**

1. Brief lead into Realistic Design Constraints
   1. The purpose of this product is to accept ground up PLA and virgin pellets to melt down and spool the material. This spooled PLA will be used for 3D printing within the local community and help to recycle waste.
2. Constraints relevant to the filament recycler
   1. Economic, Environmental and Sustainability, Social and Political, Ethics and Legal, Health and Safety, Manufacturability, and Standards

**Economic**

1. Available Budget
   1. GE 498: Pre-purchased project (Adam Johnson)
      1. Filament recycler to reuse old 3D-printed projects and turn them into usable printing filament
      2. Adam Johnson set a budget cap of $5,000, preferring to keep the cost around that of other commercially available options for recycling filament
   2. Future:
      1. In the future, the designs will be open source, so there will not be a cost to publishing the designs on Github.
2. Production Cost vs Competition
   1. Production Cost
      1. Salaries and Benefits: minimal due to the product being a senior design project. Also, there will not be a cost for commercial sale as it is meant to be open source.
      2. Prototypes: cost around $2,100 to build each unit
      3. Travel and Transportation: Due to the large and heavy size of our machine there may be transportation costs. However, the extruder will be moved in the back of a pickup truck and it is shipping locally, so there is little cost to us.
   2. Competition
      1. There are several other similar products such as the Felfil Evo, which is currently priced at $1,199. [1] This product does not come with all the sensors that we will incorporate and will not be calibrated as well as ours.
      2. The other option is the 3Devo, which is very similar to our product but is priced a lot higher at $6000. [2] We believe that our extruder will be priced a lot lower because the engineering and R&D will be done in house.
      3. Our product does have a niche because it will be open source and cheaper than many similar products. This will encourage others to use our designs.
3. Potential Impact on the Economy
   1. Raw Material Availability
      1. PETG is a common 3D printer filament and is readily available.
      2. Steel and aluminum are common materials for manufacturing that would be readily available for producing this product. [3]
   2. Import/Export consideration
      1. The screw and the barrel were provided by the customer but initially were procured from Europe.
   3. Local job creation/elimination
      1. The potential for the consumer to recycle plastic will decrease the demand for purchasing new premanufactured rolls of filament. This could lead to a decrease in production thus making companies that manufacture filament have to downsize their companies and let people go.
   4. Visionary projects
      1. This project is being properly documented and will be open source so the project can be modified and used for any filament extruding purpose. Further preset settings can be programmed into the system with the optimal temperature and motor speed for different types of filament materials.
4. Maintenance cost
   1. Frequency of failure
      1. The machine should not break often if properly used due to strong materials being used with relatively low forces.
      2. A support plate and flexible coupler ensure low risk for misalignment with the motor and screw to mitigate damage.
   2. Repair and maintenance cost
      1. If a component breaks everything was designed to be easily manufactured and all purchased parts were bought from common manufacturers thus making repairs relatively cheap.
   3. Warranty
      1. There is no warranty because this is an open-sourced product so every individual will be responsible for manufacturing.

**Environmental**

1. Waste/emissions in the production phase
   1. Iron, steel, and aluminum: iron and steel are the world's most recycled materials, and among the easiest materials to reprocess [4]
   2. PETG: it is completely recyclable, biodegradable, and doesn't release gases [5]
   3. Silicon: During the production of the sensors and circuit board, there will be minimal silicon waste.
2. Waste/emissions when in use
   1. 3D printing filament materials have been known to emit volatile organic compounds which can potentially lead to a variety of health conditions when inhaled. Polylactic acid (PLA) is the main plastic that will be recycled by the system, which emits the least amount of particles in comparison to other commonly used materials [6].
3. Lifetime
   1. All steel components made for this project have a lifespan that will outlast all other components as long as they are properly maintained.
   2. The aluminum nozzle piece will need to be replaced once the user notices the tolerances of the filament are outside of the desired range because of wear on the aluminum. This lifespan will be dependent on the plastic material used, the temperature the device is used at, and the number of hours the recycler is used.
   3. The parts made from PETG, if used properly, should last the lifetime of the system.
4. End of life
   1. All metal materials could be taken to a scrap facility to be recycled
   2. The electronic components are often not recycled and end up in landfills; Americans throw away an estimated $55 billion in e-waste material annually [7]. The consumer could take the electronic components to a special recycling facility that does recycling for electronics.
   3. The PETG can be recycled by a system similar to the product being discussed in this document.

**Social and Political**

1. Recycling and reducing waste
   1. The filament extruder will promote recycling. The filament recycler will take 3D printed parts and recycle them into new filament spools. This will make it easier for people to recycle failed or old prints and prevent plastic from winding up in the landfill. Recycling will help keep the planet green and prevent wasted 3D printed plastic.
2. Mass production
   1. The question of whether there is enough demand on the market for this product will not deter development as it will be open source. The rise and fall of this product’s popularity is not a concern at this time.

**Ethics and Legal**

1. Ethical
   1. The extruder due to the heating elements and moving parts could become a danger to the user or those nearby. However, several engineering designs will improve safety. The heating element will be isolated and moving parts will be contained. These safety features will go above and beyond OSHA standards so the system will be safe.
2. Legal
   1. One legal concern is that there may be a few safety hazards for the operator. However, there will be several safety features that will protect the user (see the health and safety section below).

**Health and Safety**

1. Health and safety of the direct user
   1. Fire Hazards. Because the extruder will be heating the plastic to 180 degrees Celsius, there are concerns that something might catch on fire. To protect against this, there will be several safety measures such as insolation.
   2. Burn Hazards. To prevent the user from burning himself, all exposed surfaces will remain below 49 degrees Celsius. This will be shown through many tests.
   3. Safety Hazard. One safety concern is that a moving part might injure the user. To prevent this all moving parts will be enclosed according to OSHA standards (see standards section below).
2. Health and safety of the public
   1. The direct public may come to observe the filament extruder for educational purposes. The product does not have any exposed parts that are over 49 degrees Celsius or moving parts. There will also be a remote control interface so that the public does not have to get close.
   2. The product does not have any small parts and all moving parts are enclosed so this will protect those nearby. There will also be a remote control interface so that children do not have to get close.
3. Health and safety of kids
   1. There will be kids who will be nearby observing the machine. The product does not have any small parts and all moving parts are enclosed so this will protect those nearby. There will also be a remote control interface so that children do not have to get close.

**Manufacturability**

1. Purchased Products and Parts
   1. The project consists largely of parts purchased from large and stable suppliers such as Digikey, Dwyer, McMaster, and Adafruit. This will ensure that the parts will remain commercially available so that others will be able to replicate this design in the future.
2. Manufactured and Created Parts
   1. Some pieces of the project have been created or modified by the team, such as metal that has been cut and welded or printed circuit boards (PCBs) that have been designed and ordered. Detailed schematics and designs will be included with the open-source documentation so that the project will be replicable, and any parts that have been modified or built from scratch will use widely commercially available materials as their base.
3. Construction and Assembly
   1. The system will be fully built and assembled by the filament recycler team. It will be disassembled when given to the customer for transportation.
4. Sizing Connections
   1. Similar sized connection types were used when possible. Due to the different sizes and load capabilities different connection types were needed throughout the filament recycler.
      1. The nozzle uses 0.25”-20 bolts.
      2. The supports will use .332in (Size Q drilled) bolts.
5. Modular System
   1. The filament recycler will utilize a modular structure so that it can be disassembled for transport and storage. This ease of disassembly will also make replacing parts of the system easier.

**Standards**

1. The user will not be able to reach into any moving parts according to OSHA standard in Table O-10 of OSHA 29 CFR 1910.217(c)(2)(i)(a) and 1910.217(c)(2)(i)(b) [8]
2. The insulation around the heating coil will not reach hot surface temperature according to ASTM C411 - Standard Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation. [9]
3. All emergency stops switches or buttons must be red in color according to OSHA 29 CFR 1910.144(a)(1)(iii) [10]

**Conclusion**

1. Summarize key constraints
   1. Manufacturability - the customer wants this product to be fully open source and as easy to manufacture as possible so that the product can be easily repeated.
   2. Health and Safety - the project will be used for educational purposes around small children so all aspects of the project need to be closely regulated and dangers need to be eliminated.
   3. Economic Constraint - the customer would prefer that our product be less than the average market value (of $6000) and that manufacturing would be minimized to promote ease of reproduction. A similar mentality was applied to the order of components such that other producers can easily obtain the same components.

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