

ERC Starting Grant 2023
Research proposal [Part B1]

My project title

ACRO

- Principal investigator (PI): My Name
- Host institution: My University
- Full title: My project title
- Proposal short name: ACRO
- Proposal duration: 60 months

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Section a: Extended Synopsis of the scientific proposal [max. 5 pages]

i DRAM in a nutshell

The aim of DRAM is to establish a blueprint methodology for the implementation of micro-chain values of distributed recycling at a urban territorial level. We seek to the achievement of a three-level target: (1) Undertand the establishment of a free-open source technical ecosystem that can be printed, 2) to establish a set indicators to possible help decision-makers and in the local implementation of these initiatives in Europe/(America?), 3)

1. The State of the art.

1 Plastics and the Antropocene: a change is needed

Plastic waste contamination is one of the relevant stratigraphic indicator of what is recently considered the Anthropocene era¹. The anthropocene frames the humans not only as biological but as geological force acknowledging the new status of humanity given the different markups in the ecosystems that are impacting the stability of the earth system. The current globalized manufacturing activities have played a major role not only as motor for the economic development, but also the transgression of the planetary boundaries². For instance, the plastic production increased at compound annual growth rate of 8.4%, passing from 2Mt in 1950 to 368Mt in 2019, but about 9% have been recycled while 79% was accumulated in landfills or the natural environment³. Soil and marine plastic pollution shows ecological, biogeochemical and physical thresholds and they are becoming a key component of the planetary boundary threat associated with chemical pollutants. The delay that implies to put in place an alternative productive model is the main paradox in this issue. This implies the scientific questions on how to manage the huge amount of waste already present in the nature and the plastic waste generated in the short term expecting that materials science and industrial corpus develops feedstock in corcordance with the biogeological cycles. Indeed, the rebound effect of the global mass production paradigm demands to rethink the paradigms of the means of production given the ecological degradation.

Getting stuck with the scale paradigm for recycling

Different routes have been developed for plastic recycling (see Figure)

From an energy and environmental perspective, the scientific literature⁷ proves that the mechanical recycling strategy is the most suitable plastic waste management option for relatively clean and homogeneous plastic and bioplastic waste streams compared to landfilling or incineration alternatives. However, transitioning to sustainable plastics in the manufacturing of plastic products, parts, and packaging is influenced by the complex interconnections between polymer producers - petrochemical companies- [10], converters [11], brand owners or manufacturers [12], retailers and consumers [13], and recycling operators [14], as well as the influences of policymakers in wider economic and societal changes [11]. Economic, social, political and technological barriers must be overcome for sustainable plastic management [9].

Major long vision: Circular and commercial production

Today, a major societal issue rely on how to conceived socio-technical 'circular units' for manufacturing that include all ecosystem externalities considering the carrying capacity of the ecosystem. Indeed, the trend is reinforced by the fact that by 2050, it is expected that about 70% of the world's population will live in urban settlements⁸. Urban cities will be responsible for non-negligible environmental impact, producing about 50% of global waste, and 75% of greenhouse gas emissions which affects the sustainability of cities and the quality of city life⁹. The manufacturing and re-cycling approaches will need to converge in a post-growth economy context need to integrate the related societal issues of resource scarcity and waste accumulation in the urban settlements^{8,10}.

Open source digital commons for 'Design global / Manufacturing local'

As an alternative of globalized manufacturing values chains, a major trend in the development of production systems seeks to establish an urban production model with decentralized and distributed characteristics¹¹. Aiming at a 'design global / manufacturing local' seems a proto-industrialization¹² tran-

sition that is taking place in urban settlements that could have a major impact in the next short future [1]. The Open Source Appropriate Technology (OSAT) and P2P approaches have been seen as potential drivers to propose an alternative globalisation manufacturing paradigm [13]. The open source additive manufacturing technology, also known as 3D printing, has played a major role in the idea of democratization of manufacturing means [1]. Thousands of open-source products are shared by the global community from consumer goods to scientific [1] and medical equipment [1]. This model has been proven to be effective for emergency manufacturing during the COVID-19 pandemic [14]. This is a driver for communities to fabricate their own products for less than the price of purchasing them. In that sense, the concept of urban factory is evolving as a disruptive approach and is the materialization of this manufacturing paradigm. The urban factory is defined as “a factory located in an urban environment that is actively utilizing the unique characteristics of its surroundings”. It creates products with a focus on the local market and allows customer involvement during value creation [11, 15].

Distributed recycling for additive manufacturing: a promising inclusion

Since 2014, I have been working on the validation of the open-source 3D printing as a robust manufacturing system [16], but also as a potential enabler of the mechanical recycling [17, 18] of plastic waste material. Distributed recycling (See Figure 1) is a breakthrough promise in the constitution of a micro-circular industry units to validate the technical feasibility, and several technologic pathways are maturing to allow individuals to recycle waste plastic directly by 3D-printing it into valuable products.

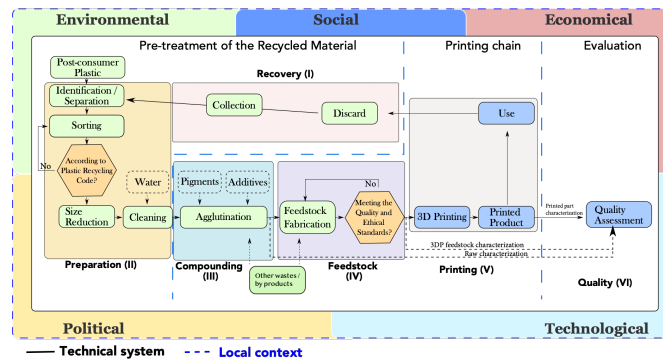


Figure 1: Distributed recycling via additive manufacturing. Source

DRAM: why now?

To appreciate the ground-breaking scientific nature of this idea, let me state that the most adopted form of additive manufacturing is fused filament fabrication, which is a material extrusion process [1]. DRAM starts with waste plastic that is produced everywhere from packaging to broken products. It is washed, dried and then ground or cut into particles using a waste plastic granulator or office shredder. Next, the particles are either converted to 3D-printing filament using a recyclebot or printed directly. Filament made with a recyclebot costs less than 10 cents per kg, whereas commercial filament costs \$20/kg or more. This can produce valuable products at remarkably low costs. For example, using a recyclebot/3D-printer combination can produce over 300 units (e.g., camera lens hoods) for the price of one such item listed on Amazon.com. The raw material for FFF can be manufactured economically using distributed means with a waste plastic extruder (often called a “recyclebot”) [19]. Recycling of plastic waste into 3-D printing filament decreases the embodied energy of filament by 90% compared to traditional centralized filament manufacturing using fossil fuels as inputs [20, 21]. Distributed recycling fits into the circular economy paradigm [22–24], as it eliminates most embodied energy and pollution from transportation between processing steps. Additionally, open-source investment should result in an extremely high return on investment (ROI) in free and open source hardware [ref?]. This makes distributed recycling and additive manufacturing (DRAM) environmentally superior to other methods of plastic recycling.

However, using a systematic literature review, I realized that the system maturity and the technical value chain for the implementation of a community-driven of plastic recycling is ambiguous [25]. Major efforts in the scientific literature have been only concentrated in the materials and technical validation. However, the system validation remains to be difficult to implement. More in deep, the analysis of the

holistic impact that this process can have in the context of a city remain vague, if not, not treated at all. In particular, this will be important if a recycled resources industry (RRI) is starting to be conceived inside the cities. RRI is seen as driver consists of a series of activities related to recycled resources – e.g., recycling, refining, remanufacturing, etc. – aspiring to mitigate the negative externality caused by the linear economy²⁶. The sustainable development of the RRI has thus been highlighted on many countries' agendas to promote the circular society^{27–29}, as well as the goals of carbon peak and carbon neutralization. The main difficulty remains to make affordable the use of new secondary material applicability by the industry³⁰, but at the end, for urban planning and policymaking to make concrete the ambition of circular economy inside the urban and regional settlements.

2. Ambition, objectives

Plastic recycling remains at systemic problem, and *there is a urgent necessity to better understand the major barriers and drivers to design and deploy sustainable and inclusive micro-recycling value chains inspired on the “Design Global / Manufacturing local” principles*. How to develop an industrial ecology network for recycling, given the uncertainty of the thresholds of sustainability, ecological and social for these type of projects ?

How to deal with the technological choices for establishment ‘local circular units’? These question are not yet well answered.

SDRAM's goals: a systemic blueprint to understand the distributed recycling approach

The purpose of SDRAM project is create a systemic blueprint to better understand the design of socio-technical distributed distributed recycling approach in urban settlements.

As a systemic blueprint, i mean to consider the technical, system and valuation layers (See Figure XX). The major gap that currently prevents from exploring the potential of distributed recycling relies on a missing holistic understanding of the design for sustainability^{31,32} of socio-technical system in a context of ‘Spaceship Earth’, as an apt metaphor to chart the boundaries for a safe planet^{sterner2019?}. This implies going from the technical (molecule , process unit) to the ecosystem impact of the implementation.

A challenging task

From a major scientific, DRAM seeks the achievement of a three-level target (See Figure XXX). : 1) The design of an open source appropriate technical ecosystem (OSAT). 2) Develop propositioning a systems dynamics methodology 3) Develop new forms of valuation of these micro-values chains that integrate ecosystem characteristics.

- *the development of appropriate technologies is fundamental.* Technological choices and applications that are small-scale, economically affordable, decentralised, energy-efficient, environmentally sound and easily utilized by local communities to meet their needs are needed [1]. Therefore, the trend in appropriate technologies is towards relatively simple and non-complex technologies, to complete the technological mix to be capable of plastic recycling from the identification of material, cleaning, sorting. The development of open hardware scientific are considered as an excellent choice to reduce the cost [1]. The creation of a technical blueprint is there is no a database that include is regarded as the front of

- *Systemic design thinking is needed to identify major feedbacks in the strategic, the tactical and the operational decisional levels.* Reconciling urban development and industrial development is not an easy task. Particularly, in the use of plastic materials. Thus, the type of information that the decision-makers take into account is relevant at the moment to put in place industrial systems.

- *Create a new forms valuation* From the ecological economics science, it is stated to analyse socio-technical systems beyond the economics [1], to include new form of pluralisms valuation to include the ecological interactions[1].

In order to allow exploration of a new science domain, based on the multi-echelle and multi-acteur.

3. The Methodology

SDRAM implements a methodology made of four working packages (WP), as illustrated in Fig.

127 The first phase correspond

128 **### Axe 1: development of a open-source technodiversity for recycling**

129 **Axe 1: Systemic analysis in function of the local territory**

130 ■ Development of methodology to identify potential urban disposal sites connecting

131 **Axe 3: Circular business model for recycled communities**

132 ■ ...

133 **Axe 4: Prospective recommendation through delphi analysis?**

134 ■ ...

135 **An Impact project**

136 **Resources and budget**

137 **The research team**

138 The budget required for the development of SDRAM is XXX €. The most significant cost is the personnel cost (XXXX € - XX %). Minor cost cover the purchase of experimental open hardware equipment (XXXX € - XX %), travels for dissemination of results (XXXX € - XX %), Open access fees for at least 8 publications (XXXX € - XX %).

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