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
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> 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.

Arriving to the limits for global and mass manufacturing paradigm

Plastic waste contamination[1], climate change [], biodiversity loss[ref?] are relevants stratigraphic indicator of what is recently disscused as the Anthropocene era. 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. Since 250 years, 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 boundaries[2]. The economic development was often triggered and catalyzed by the introduction of new technologies and concepts for value creation, as shown by the historical industrialization trends.

The mass manufacturing socio-technical systems is understood as a deep transition[3], where a co-evolution of single unit productions systems, interconnected systems, and industrial modernity have been gradually intensified various forms of environmental degradation while not being able to solve recurring issues of social inequality in connection to unequal access to healthcare, energy, water, food, mobility, security, finance, education, and communication. Manufacturing requires materials as well as human and physical capital to produce goods. Even if the importance of manufacturing as the heart of an economy has not changed, the way of producing goods and the setup of the location start to change dramatically.

The design of manufacturing systems developed the implicit assumption that ecological systems have nearly endless capacity to provide resources and adsorb wastes. This blindness in the engineering vision can be explaining by the fact that at the beginning of the technological industrialization, the human activites' impacts on the earth remained marginal. This scenario is not true today.

Major long vision: Circular and convivial production

Today, a major societal issue rely on how to conceived socio-technical 'circular units' for (re-)manufacturing that are resilient[ref?], adaptable[ref?] and evolutive in urban settlements. The reuse, repairing, recycling, decycling 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[4,5]. Indeed, today the establishment of this socio-technical systems need to include all ecosystem externalitites and the carrying capacity of the ecosystem to claim to sustainability. 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 settlements[5]. 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 life[6].

Open source and 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 characteristics[7]. Aiming at a 'design global / manufacturing local' seems a proto-industrialization[8] transition that is taking place in urban settlements that could a major impact in the next short future [@]. The Open Source Appropriate Technology (OSAT) and P2P approaches have been seen potential drivers to propose an alternative globalisation manufacturing paradigm[9]. The open source additive manufacturing technology, also know as 3D printing, have played a major role in the idea of democratization of

Figure 1: Elephant

manufacturing means [@]. Thousands of open-source products are shared by the global community from consumer goods to scientific[@] and medical equipment[@]. This model has been proven to be effective for emergency manufacturing during the COVID-19 pandemic[10]. This is a driver 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[7,11].

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[12], but also as a potential enabler of the mechanical recycling[13,14] of plastic waste material. Distributed recycling (See Figure 2) 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.

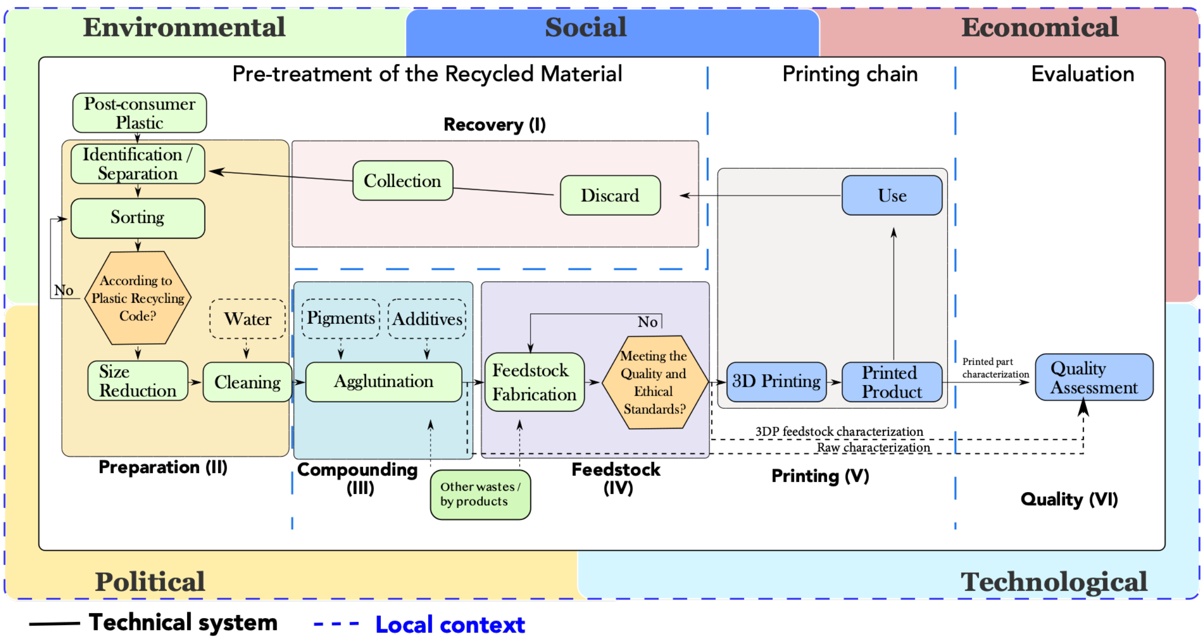

Figure 2: Distributed recycling via additive manufacturing. Source

DRAM:

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 [@]. 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")[15]. 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[16,17]. Distributed recycling fits into the circular economy paradigm[18–20], as it eliminates most embodied energy and pollution from transportation between processing steps. Additionaly, 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, from a scientific perspective using a systematic literature review, I realized that the global system maturity the technical value chain for the implementation of a community-driven of plastic recycling is ambiguous[21]. 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.

Moreover, I have been leading the implementation of the demostrator in the framework of an European project. which is a sustaiability trasition for the urban plastic in a living lab approach.

In particular, this will is important if a recycled resources industry (RRI) is starting to 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 economy[22]. The sustainable development of the RRI has thus been highlighted on many countries' agendas to promote the circular society[23–25], 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 industry[26], but at the end, for urban planning and polycimaking to make concrete the ambition of circuclar economy inside the urban and regional settlements.

2. Ambition & objectives

The material rarefaction[27], the ecological integration[ref?] and the resilience of production systems[ref?] remains a systemic problem and it calls for pushing forward the boundaries of knowledge in the fuzzy front-end design phases of socio-technical manufacturing configurations. There is a urgent necessity to better understand how to develop and implement manufacturing socio-technical demonstrators at urban levels to unleash a sustainability transition towards appropriate and inclusive micro-manufacturing and recycling values chains inspired on the *"Design Global / Manufacturing local" principles.* By exploring the case of Green Fablab At Octroi Nancy, **the purpose of SDRAM project is create a systemic blueprint methodological approach to fully expand the frontiers of the design socio-technical manufacturing systems as a sustainable transitions in urban settlements.** To do so, the SDRAM project aims to deep understanding of the three major layers and the boundary object between them:

1. Urban space in the lens of material rarefaction and urban manufacturing opportunity.
2. Design for open source appropriate technologies as technological baseline, and
3. Pluralism (e)valuation of socio-technical system alternative to mass production in frame of a urban sustainability transition.

   The ambition of this project is to open up the possibilities of a new field of socio-technical design of distributed and circular urban production systems based to the scientific community.

Manufacturing and an urban priority for relience and agility. **To develop....**

The open-source appropriatte technology as alternative has just started. In this project, the 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 is fundamental[@]. 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 scietnific are considered as an excellent choice to reduce the cost [@]. The creation of a technical blueprint is there is no a database that include is regarded as the front of A complete technological mix aims to empower citizen in the. to To identify the pertinent The establishment of development of a technological open source maturity level focalised on the distributed recycling of the design of an open source appropriate technical ecosystem (OSAT).

Systemic design thinking 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. Thus, the type of information that decision-makers take into account is relevant at the moment to put in place industrial systems.

Pluralism valuation for emerging industrial micro-values chains that integrate ecosystem characteristics. It is urgent to expand the boundaries for engineering design from the lowest molecular level to the process level, and from individual process to the higher levels of value chains, ecosystems and the planet[28]. We need to integrate ecological carrying capacity since the fuzzy front end phase of an industrial systems. However, the integration of ecological aspects in the decision-making seems not evident given the complexity to define the boundaries and interactions of industrial and ecological systems.

A challenging task for a systemic blueprint

The major gap that currently prevents from exploring the potential of alternative distributed manufacturing relies on a knowledge gap in terms of the maturity in the connection between the unit-facility-urban levels including the respective boundaries objects that needs to be considered between the layers. From a design for sustainability[29,30] perspective, this implies the aid-decision tools to help makers, practitioners and decision-makers in the implementation phase considering the technosphere (molecule, material, process unit) but also the also to the ecosystem impact. Therefore as a systemic blueprint, I aim to make linkage of the micro-meso-macro levels of the technical, system and valuation layers embed in a urban spatio-temporal context (See Figure network)

3. The Methodology

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

The aim of WP1 is to set the literature baseline for an integrative and critical analysis of the urban production systems integrating three essential issues: sustainability, resiliency, and agility into a circular economy praxis. This working package gives the insights for the WP2, and WP3, which are key of the project. The WP2 seeks to consolidate systematize a design for OSAT, establishing a theoretical maturity level index that could foster the consolidatation of the OSAT in SME's. The WP3 aims to propose a urban closed-loop system network integrating integrates Finally, WP4 is dedicated to the experimentaiton of and anlaysis of the several demostrators of the urban circular manufacturing taking into case study the implementation of the Green Fablab Project at Nancy-Fr. Workpackages are synthetically detailed hereinafter.

WP 1:

The achievement to SDRAM target relies the urban spatial characteristics as an entry point of the design of the socio-technical system possible identify two major output. (1.1) a predictive cartography based tool with possible secondary materials niches at the urban level. (2.2)

WP 2: Maturity level and technodiverstity level of the open source appropritte technology

The main purpose of this task is to build a Tasks: (2.1) definition of a Scientific literature and critical analysis on advantages and barriers of the implications of the open-source appropritte technologies for recycling.

WP 3: Systemic analysisi in function of the local territory

- Development of methdology to identify potential urban disposal sites connecting
- ANalyse the political, method

it is stated to analys socio-technical sytems beyond the economics [@], to include new form of pluralims valuation to include the ecological interactions[@].

WP 4: Pluralism (e)valuation of the new alternative manufacturing systems

WP4 is devoted to the implementation and experiementaiton of the dsitributed net

To pass from ecodesign to a for design for sustainability, ten different models at operational, tactical, and strategical levels have been identified[30]. One strategical point in sustainability relies on the economic valuation of ecosystem goods and services framework. This approach gives an important framework highlighting their importance for society and human welfare. However, there is a need to explicitly account for their contribution when designing and developing products and services[31].

The WP4 aims to consolidate start a longitudinal study of different initiatives of to give a to possible establish a major understanding of the implementation

(4.1) Prospective recomendation through the participation of

3. Conceptueal risk and fesability assessment

SDRAM is a high operation and conceptual-risk project mainly because as a soio evaluation of the pactful

4. An Impact project

5. Resources and budget

The research team

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

References

1. De-la-Torre GE, Dioses-Salinas DC, Pizarro-Ortega CI, et al. New plastic formations in the Anthropocene. *Science of The Total Environment* 2021; 754: 142216.
2. O'Neill DW, Fanning AL, Lamb WF, et al. A good life for all within planetary boundaries. *Nature Sustainability* 2018; 1: 88–95.
3. Kanger L, Bone F, Rotolo D, et al. Deep transitions: A mixed methods study of the historical evolution of mass production. *Technological Forecasting and Social Change* 2022; 177: 121491.
4. Kallis G, Kostakis V, Lange S, et al. Research On Degrowth. *Annu Rev Environ Resour* 2018; 43: 291–316.
5. Savini F. The circular economy of waste: Recovery, incineration and urban reuse. *Journal of Environmental Planning and Management* 2021; 64: 2114–2132.
6. Riffat S, Powell R, Aydin D. Future cities and environmental sustainability. *Future Cities and Environment* 2016; 2: 1.
7. Herrmann C, Juraschek M, Burggräf P, et al. Urban production: State of the art and future trends for urban factories. *CIRP Annals* 2020; 69: 764–787.
8. Sabel C, Zeitlin J. Historical Alternatives to Mass Production: Politics, Markets and Technology in Nineteenth-Century Industrialization. *Past & Present* 1985; 133–176.
9. Heikkinen ITS, Savin H, Partanen J, et al. Towards national policy for open source hardware research: The case of Finland. *Technol Forecast Soc Change* 2020; 155: 119986.
10. Pearce JM. A review of open source ventilators for COVID-19 and future pandemics. *F1000Research*; 9. Epub ahead of print 2020. DOI: 10.12688/f1000research.22942.2.
11. Ijassi W, Evrard D, Zwolinski P. Characterizing urban factories by their value chain: A first step towards more sustainability in production. *Procedia CIRP* 2022; 105: 290–295.
12. Cruz Sanchez FA, Boudaoud H, Muller L, et al. Towards a standard experimental protocol for open source additive manufacturing. *Virtual and Physical Prototyping* 2014; 9: 151–167.
13. Cruz F, Lanza S, Boudaoud H, et al. Polymer Recycling and Additive Manufacturing in an Open Source context : Optimization of processes and methods. In: *Solid Freeform Fabrication*. Austin, Texas, 2015, pp. 1591–1600.
14. Cruz Sanchez FA, Boudaoud H, Hoppe S, et al. Polymer recycling in an open-source additive manufacturing context: Mechanical issues. *Additive Manufacturing* 2017; 17: 87–105.
15. Baechler C, DeVuono M, Pearce JM. Distributed recycling of waste polymer into RepRap feedstock. *Rapid Prototyping Journal* 2013; 19: 118–125.
16. Kreiger M, Pearce JM. Environmental Impacts of Distributed Manufacturing from 3-D Printing of Polymer Components and Products. *MRS Proceedings* 2013; 1492: 85–90.
17. Zhong S, Rakhe P, Pearce J. Energy Payback Time of a Solar Photovoltaic Powered Waste Plastic Recyclebot System. *Recycling* 2017; 2: 10.
18. Zhong S, Pearce JM. Tightening the loop on the circular economy: Coupled distributed recycling and manufacturing with recyclebot and RepRap 3-D printing. *Resources, Conservation and Recycling* 2018; 128: 48–58.
19. Garmulewicz A, Holweg M, Veldhuis H, et al. Disruptive Technology as an Enabler of the Circular Economy: What Potential Does 3D Printing Hold? *California Management Review* 2018; 60: 112–132.
20. Despeisse M, Baumers M, Brown P, et al. Unlocking value for a circular economy through 3D printing: A research agenda. *Technological Forecasting and Social Change* 2017; 115: 75–84.
21. Cruz Sanchez FA, Boudaoud H, Camargo M, et al. Plastic recycling in additive manufacturing: A systematic literature review and opportunities for the circular economy. *Journal of Cleaner Production* 2020; 264: 121602.

22. Wang M, Liu P, Gu Z, et al. A Scientometric Review of Resource Recycling Industry. *International Journal of Environmental Research and Public Health* 2019; 16: 4654.
23. Leipold S, Weldner K, Hohl M. Do we need a 'circular society'? Competing narratives of the circular economy in the French food sector. *Ecological Economics* 2021; 187: 107086.
24. Hobson K, Holmes H, Welch D, et al. Consumption Work in the circular economy: A research agenda. *Journal of Cleaner Production* 2021; 321: 128969.
25. Jaeger-Erben M, Jensen C, Hofmann F, et al. There is no sustainable circular economy without a circular society. *Resources, Conservation and Recycling* 2021; 168: 105476.
26. Klotz M, Haupt M, Hellweg S. Limited utilization options for secondary plastics may restrict their circularity. *Waste Management* 2022; 141: 251–270.
27. Hultman J, Corvellec H, Jerneck A, et al. A resourcification manifesto: Understanding the social process of resources becoming resources. *Research Policy* 2021; 50: 104297.
28. Martinez-Hernandez E. Trends in sustainable process design—from molecular to global scales. *Current Opinion in Chemical Engineering* 2017; 17: 35–41.
29. Ceschin F, Gaziulusoy I. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Design Studies* 2016; 47: 118–163.
30. Rocha CS, Antunes P, Partidário P. Design for sustainability models: A multiperspective review. *Journal of Cleaner Production* 2019; 234: 1428–1445.
31. Diwekar U, Amekudzi-Kennedy A, Bakshi B, et al. A perspective on the role of uncertainty in sustainability science and engineering. *Resources, Conservation and Recycling* 2021; 164: 105140.