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## Terra Recovery

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|---|---|

The Terra Recovery Project

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*Turning yesterday's waste into tomorrow's products*

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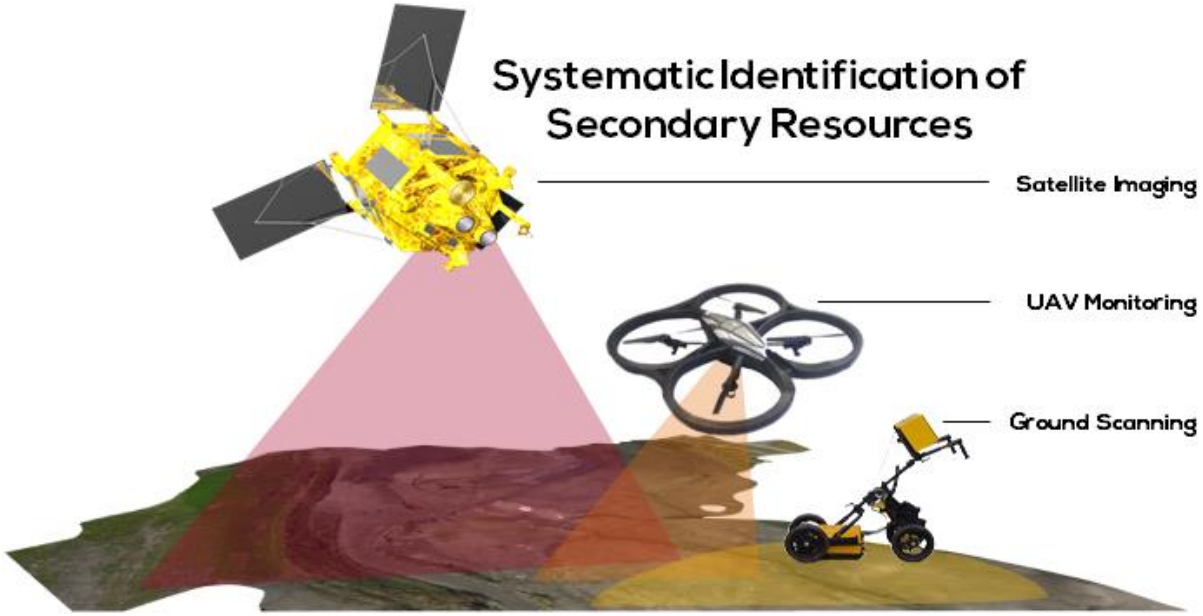


## Background

Historically, secondary raw material deposits, such as landfill or mine tailings, have been commonly associated with their negative aspects: long-term methane emissions, local pollution, ground water pollution, and limitations on urban development. The OECD says 3 billion tons of trash a year will contribute to landfills worldwide by 2030, up from 1.8 billion in 2013. However, recent endeavours to reuse waste materials found in dumps suggest the potential of this number as a vast new resource as opposed to a useless burden. Landfills are a largely untapped resource for many strategic metals. Valuable recyclable materials formerly regarded as waste can be mined from landfills, providing a new source of such material. The scope of this resource is vast: In the UK alone, 2 billion tons of waste sit untouched in landfills. Such material has potential to provide a new supply for declining supplies of metals such as the platinum group elements and rare earths, both of which are found frequently in landfill or mine tailing sites. In addition to providing an untapped resource for many strategic elements, landfill mining alleviates space and local pollution concerns related to landfills. Benefits include reducing pollution or the risk of pollution from substandard landfill or dump sites, reclaiming soil, extending the life of the landfill by reducing the volume of waste or reducing the area of land the landfill occupies, recovering materials such as aluminium and ferrous metals, and producing energy at municipal waste-to-energy facilities. Last but not least, disseminating the value of hidden resources in landfills across society, policy makers, governmental officials and industry players is crucial to enable a paradigm shift from our current linear – take-make-waste – economy towards a circular economy.

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## Description of Project Idea

Landfill mining is not a new idea, but it is rarely executed because the contents and value of materials within any one landfill varies significantly. Existing projects select landfills without a comprehensive down-selection process of economic viable sites and, thus, have high risk of failure because there is little to no information on the actual contents and their value. The principle focus of the Terra Recovery Project will be the systematic identification and characterisation of high value landfills. The project will combine satellite data, public records and cutting edge sensor technologies from space and other industries to assess landfills to an unprecedented level of quality. We will kick-start a new industrial symbiosis where we turn yesterday's waste into tomorrow's products. With this project, billions of tons of buried resources will go back into the product life cycle of many industries that will secure efficient and sustainable usage of resources. The general environmental impact is significant because many recycled materials, such as aluminium, use less energy and produce less $CO_2$ as compared to converting raw primary materials into usable products. Finally, even modern landfills created with the most rigorous environmental protection methods will breakdown over time releasing toxic materials into the environment. Our project monetizes recovery and clean-up of these potential environmental risks before they can impact the lives and well-being of local communities.

## Realistic implementation

The Terra Recovery Project will employ a mix of data and remote sensing technologies to develop the models necessary to identify, characterise, and determine the economic viability of a landfill as a resource mine. Because only a small fraction of the tens of thousands of landfills across the world will initially be suitable, we are creating an efficient method to eliminate those which are not economically viable for mining and recovery. This is a multi-step process as follows and shown in *Figure 1*.

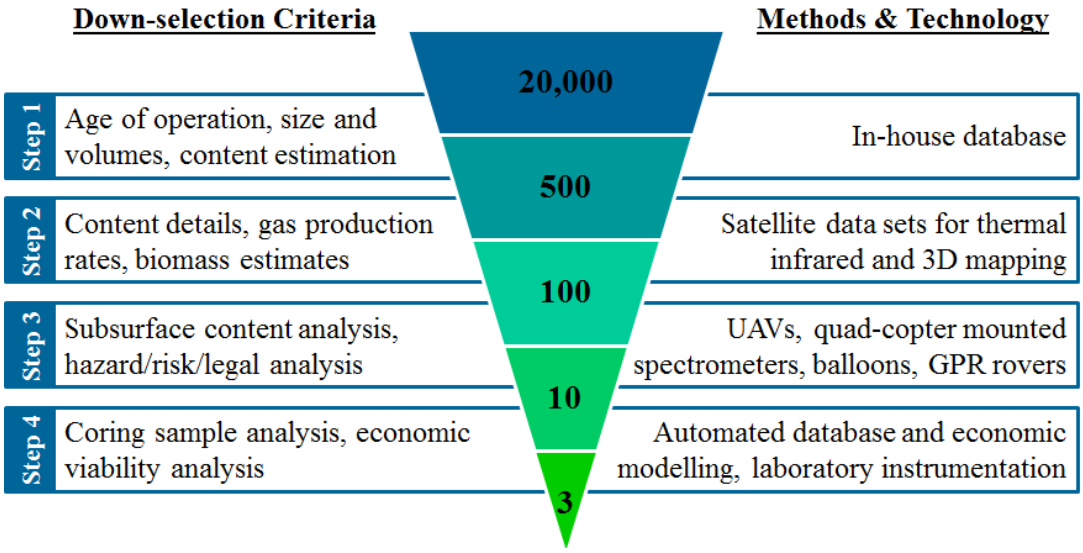


**Figure 1: Down-selection Process**

The technology required for this project includes a variety of heritage and active space technologies. These complementary technologies will be used as a comprehensive set of tools to characterize and quantify a landfill. Specific space technologies that will be used as part of the project are divided into platforms, instruments, and other technologies as described in *Table 1.*

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| Platforms | Instruments | Other Technologies |
|---|---|---|
| • Rover<br>• UAV<br>• Weather balloon<br>• Satellite | • Thermal infrared spectroscopy<br>• Spectrometer<br>• Ground penetrating radar<br>• Borehole filter radiometer | • Data analysis software<br>• Quad-copter systems |

**Table 1: Space related applications**

During the first project phase, the primary activity is the development of the data tools and expertise required, testing and adaptation of sensor and satellite technology and the development of algorithms for the economic models. Secondarily, the project will offer as a service the many unique capabilities it has developed to quickly and efficiently analyse various properties of landfills and other similar sites. Revenue from these offerings can help defray on-going operational and R&D expenses.

## Results expected

We expect to unlock a century's worth of resources presently trapped in unknown graves around the world. Key outcomes include

- Identify the contents and location of landfill resources
- Recover lost resources and close the recycling loop
- Reduce environmental hazards to local communities
- Drive emerging technologies to increase waste recovery rates

Key capabilities that we will develop in order to systematically identify economically mineable resources from landfills include:

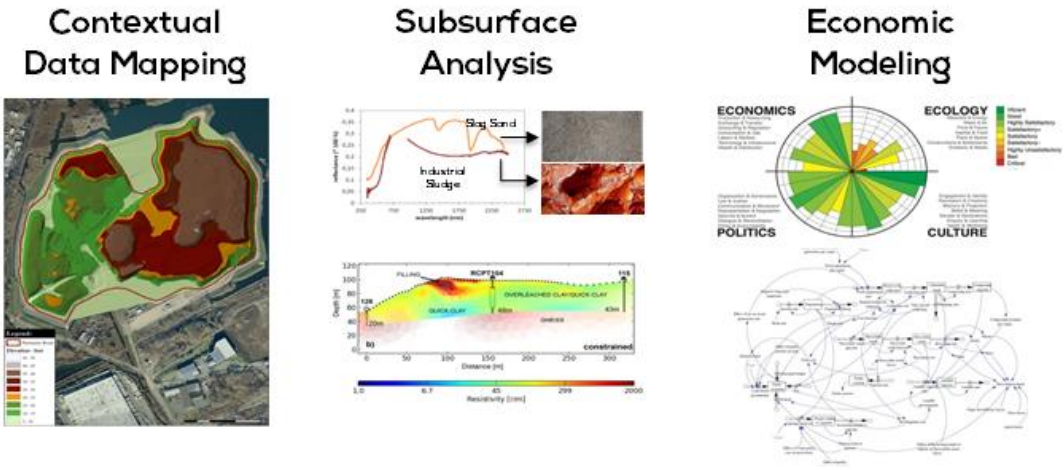


**Figure 2: Key capabilities**

The Terra Recovery Project seeks to address the needs of resource recovery firms who have an interest in landfill mining, but are unable to invest in large projects to extract resources due to the inherent uncertainty and risk. Specifically, there are risks that (i) sufficient valuable materials can be extracted and sold to compensate for the costs of developing the site, and (ii) the recovery firm will uncover and assume responsibility for environmental hazards, such as exposing hazardous materials and leaking pollutants into surrounding water tables. The main economic benefit that this project offers resource recovery firms is a significant reduction of these risks, such that the expected value of exploiting a landfill is increased to the point that it becomes a profitable investment. A landfill mining project can be de-risked first, and foremost, by identifying the type and abundance of materials in the site, and associated extraction costs. In this sense, this project is akin to gold

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prospecting services in the mining industry. A landfill can be further de-risked by modelling the probability and cost of exposing and mitigating environmental hazards.

This project provide specific benefits to many different stakeholders across the EU and globally. First, it provides key business information for waste management companies, material recovery or mining companies in order to economically mine landfills. Second, it enables governmental agencies to understand their landfill resource landscape and its potential to move towards a circular economy. Third, it increases transparency to local communities and drives countermeasures to reduce environmental hazards from landfill leakages. Last, with the expected project results emerging waste separation, recycling and waste-to-energy technologies can increase their waste recovery rates and their economic efficiency due to better understanding of material recovery content in landfills.

The Terra Recovery Project aims to become a central approach to identify secondary raw materials. The current industry standard is to select an old landfill without conducting a down-selection process and start to mine it with little information on the economic viability of the project. Our central innovation is a systematic approach to identify, characterise, and select high value landfills. This reduces the risks and increases the potential of success. Because the current state of the art bears high risk for businesses and involved communities due to significant content variability, we will reduce these risks and enable beneficial landfill mining for all stakeholders. From our research, this industry will grow over-time because the lost and forgotten materials are only increasing in value. A step forward right now into the prospecting technologies will significantly reduce the risks which will allow fast growth of the sector, recovery of critical materials to secondary markets, and clean-up toxic materials before they leak into the local environment.

## Potential risks

One of the most important risks to overcome will be gaining credibility and support for projects by local communities where landfill sites are located. It will be of utmost importance to establish strong relationships with all stakeholders to advocate to, and educate communities. Another hurdle for the mining of landfills is the environment in which some of these products are stored since it can render them unfit for recycling. However, as landfill mining becomes more prevalent for other uses such as soil recovery and landfill life extension, new processes for cleaning and reclaiming such materials can be developed and perfected by corporations hoping to financially benefit from the recyclable co-products of their landfill mining. At that point, landfill mining primarily for the purpose of recovering strategic metals will become more prevalent.