Mi-Hy

Microbial Hydroponics:
Circular Sustainable Electrobiosynthesis

Deliverable 6.3

Data Management Plan

Dissemination Level

P CO	Public Confidential, only for members of the consortium (including the Commission Services)	☒ ☐
CI	Classified, as referred to Commission Decision 2001/844/EC	☐

Type

R	Document, Report	☒
DEM	Demonstrator, Pilot, Prototype	☐
DEC	Websites, Patent Fillings, Videos, etc.	☐
Other	(describe)	☐

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WP Leader (name and organisation): Rachel Armstrong (KUL)

Person in charge of the deliverable (name and organisation): Rachel Armstrong (KUL)

Author(s): Rachel Armstrong (KU Leuven), Neil Wiley (UWE), Ioannis Ieropoulus (SOTON), Peter Hanappe (Sony), Markus Schmidt (SONY)

Contributors: Joshua Davis (KU Leuven), Jermina Stanojev (KU Leuven), Anna Vershinina (KUL)

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List of Abbreviations

Abbreviation	Meaning
BES	Bioelectrical System
BFC	Biofaction KG
C	Carbon
C and D waste	Construction and Demolition waste
CC-BY	Creative commons attribution license
CC-0	Creative commons zero
CO_2	Carbon Dioxide
CSIC	The Spanish National Research Council
CSIP	Communications Strategy and Impact Plan (D5.2)
D	Deliverable
DOI	Digital Object Identifier
Dx.y	Deliverable y from work package x
DMP	Data Management Plan
EC	European Commission
EIC	European Innovation Council
GDPR	General Data Protection Regulation
KUL	Catholic University of Leuven
LED	Light Emitting Diode
OAI-PMH	Open archives initiative protocol for metadata harvesting
M	Month
MEC	Microbial Electrochemical Cell
MFC	Microbial Fuel Cell
Mi-Hy	Microbial Hydroponics project
N	Nitrogen
N_2	Nitrogen gas
P	Phosphorous
PID	Persistent Identifier
SO	Specific Objective
SONY	Sony Computer Science Laboratory (Sony c.s.l)
SOTON	Southampton University
SSH	Secure Shell is a network communication protocol that enables two computers to communicate
T	Task

UWE	The University of the West of England
VPN	A virtual private network establishes a digital connection between your computer and a remote server owned by a VPN provider, creating a point-to-point tunnel that encrypts your personal data, masks your IP address, and lets you sidestep website blocks and firewalls on the internet
VR	Virtual Reality
WP	Work Package

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Consortium

The Mi-Hy consortium is composed from 6 institutions: KU Leuven, Belgium (KUL), the University of Southampton, United Kingdom (SOTON), SONY Computer Science Laboratory, France (SONY), Biofaction, Austria (BFC), the Spanish National Research Council, Spain (CSIC), and the University of the West of England, United Kingdom (UWE). The specific partners and team members are detailed below:

Table 1: Overview of the Mi-Hy consortium

KUL	***Coordinating Partner, Lead Partner WP6***
Rachel Armstrong	(coordinator)
Jermina Stanojev	Research Associate Mi-Hy
Anna Vershinina	Doctoral student
Joshua David	Doctoral student
SOTON	***Lead Partner WP1***
Ioannis Ireopoulos	PI
Dibyojyoty Nath	Post-Doctoral Researcher
Jeremy Baker	Technician
SONY	***Lead Partner WP4***
Peter Hanappe	PI
Alienor Lahlou	Post-Doctoral Researcher
David Colliaux	Post-Doctoral Researcher
BFC	***Lead Partner WP5***
Markus Schmidt	PI
Camillo Meinhart	Communication
Günter Seyfried	Biohacking, Prototyping
Uliana Reutina	Biodesigner, Communication
Sandra Youssef	Communication, Stakeholder
CSIC	***Lead Partner WP3***
Jorge Barriuso	PI
Ignacio Baquedano	Post-Doctoral Researcher, online
Alicia Prieto	Senior Researcher
UWE	***Lead Partner WP2***
Neil Willey	PI

Interdisciplinarity

The consortium has complementary, interdisciplinary skills, where synergies are anticipated to generate a range of different types of data (from statistics, to photographs, models (physical, digital) and prototypes) and datasets (code) which reflect this diversity.

KUL is a pioneer of biodesign, "living" materials and "bio-bricks" working at the interface between material design, spatial systems, and digital representation. KUL provides (dedicated) computing and workshop facilities for the design, illustration, modelling, and scenario development to generate plans for prototyping processes and applications.

SOTON is a world leader in MFC science and engineering and provides a high-end 3D printing suite with multi-material fabrication and biomaterial extrusion; 5-axis CNC and heavy machining; ESEM, SIFT, GC-MS.

UWE's Envirotron at Frenchay Campus uses LED lighting that minimises environmental impact and affords exquisite control of light, enabling researchers to simulate and experiment with a wide range of independently fully climate-controllable compartments.

CSIC is a State Agency for scientific research and technological development. It's institute Center for Biological Research (CIB) offers scientific facilities for: Cell Culture; Bioinformatics and Biostatistics; Genetics and Molecular Analysis; Confocal Laser and Multidimensional Microscopy; DNA Sequencing Service; Electron Microscopy; Flow Cytometry; Gas Chromatography; Glasshouse; IBISBA-Industrial Biotechnology; Macromolecular Crystallography; Molecular Interactions; Nuclear Magnetic Resonance; Protein Chemistry; Proteomics and Genomics; and Spectroscopy.

SONY is a world leading electronics company. Sony CSL Paris was founded in 1996 and it is a small but booming research cell, using tools from complexity science, data science and artificial intelligence to investigate fundamental questions in areas as diverse as: understanding and creating music, language and communication systems, sustainability, innovation dynamics and creativity (https://csl.sony.fr).

BFC has over 10-years' experience in assessing new and emerging bio and converging technologies, bridging science, society, artists, and policy makers. They provide a fully equipped film and video production suite, multi-disciplinary workshop (wood and other biomaterials, metal, resin, electronics) for rapid prototyping and preparing interactive workshops and museum exhibitions.

Executive Summary

This document, namely deliverable D6.3 – Data Management Plan (DMP), outlines the data management plan and protection approaches employed within the Mi-Hy project. Specifically, it gives an overview of the data that will be collected during the project through the work packages (WPs) and tasks, and clarifies how these will be collected, stored, and used. This DMP is a dynamic document that will be adapted, refined, and updated throughout the course of the project, as the exact outputs of each WP, and thus the data management requirements, become clearer. This DMP will be circulated within the project consortium in M5 (March 2024), revisions will be incorporated, and the document will be submitted to the EC in M6 (April 2024).

1. Project Work Packages and Deliverables

Mi-Hy is a new circular platform and Hydroponic Bioelectrical System (BES) for urban agriculture that biologically integrates Carbon (C), Nitrogen (N) (C and N) and phosphorous (P) metabolism in plants by ***combining Microbial Fuel Cell (MFC) technology*** that *produces electricity using electrons derived from biochemical reactions*, ***with hydroponics*** that involves growing plants without soil, to optimise and valorise CO_2 and N transformation (to animal feed as the initial produce). Mi-Hy's MFC biofilm acts as a **prosthetic rhizosphere** for plant roots (which utilize symbiotic relationships between fungi and bacteria to obtain nutrients from the environment) to optimize nitrogen utilisation (via the synthesis of chlorophyll and amino acids), averting the need for chemical nitrogen sources (artificial fertilizers) and turning carbon into biomass. Mi-Hy is a fundamentally circular system, its only inputs are atmospheric CO_2, light and (household) wastewater stream (see D6.1 for further details).

1.1 Project Work Packages

Mi-Hy's boundaries, goals, deadlines, and project deliverables will be achieved through the integration of wavelength specific hydroponics with MFCs and MECs, which requires breakthroughs in **four complementary domains**. Table 2 provides an overview of Mi-Hy's WPs.

Table 2: Overview of the work packages within the Mi-Hy project

WP	Title	Lead	Name
1	BES Hardware Optimisation & Added Functionality	2	SOTON
2	Hydroponics	6	UWE
3	Cellular Characterisation & Biofilm Optimisation	5	CSIC
4	Integration (Modelling, Informatics, VR) & Final Design	3	SONY
5	Diss., Comms., Exploitation & Public Installation	4	BFC
6	Project Management & Coordination	1	KUL

The scope of the project will be defined by meeting the following **Specific Objectives (SO) which are implemented in the respective Work Packages (WPs)**:

WP1 (SO1): BES Hardware Optimisation and Added Functionality is achieved by optimising the BES components (MFC/MEC), which are characterised for integration in WP4.

T2.1. Characterising light demand algorithms. (M1-M12)

T2.2 Characterising Nitrogen Parameters in plant system (M1-M36)

T2.3 MEC Biofilm Nitrogen (M1-M40)

T2.4 Nitrogen Characterisation post Biofilm Engineering (M2-M42)

T2.5. Balancing Light, C and N. (M36-M42)

T2.6 Microbially Engineered Plant Nitrogen Uptake – Evaluation of a Prosthetic Rhizosphere Report (M34-M36).

T2.7. Hydroponics optimization for citizen science (M3-M24)

WP2 (SO2): Hydroponics parameters are **c**haracterised, namely: i) the specific wavelength for N utilisation; ii) biofilm performance; and iii) data for digital model (WP4)**.**

T2.1. Characterising light demand algorithms. (M1-M12)
T2.2 Characterising Nitrogen Parameters in plant system (M1-M36)
T2.3 MEC Biofilm Nitrogen (M1-M40)
T2.4 Nitrogen Characterisation post Biofilm Engineering (M2-M42)
T2.5. Balancing Light, C and N. (M36-M42)
T2.6 Microbially Engineered Plant Nitrogen Uptake – Evaluation of a Prosthetic Rhizosphere Report (M34-M36).
T2.7. Hydroponics optimization for citizen science (M3-M24)

WP3 (SO3): Cellular Characterisation and Biofilm Optimisation is achieved by:

i) Identifying the specific electroactive microbial components for MFC (prosthetic rhizosphere).
ii) Characterising metabolic components for the MEC.
iii) Testing the microbial data parameters for WP4 model**.**

T3.1 Selecting Microbial Strains and Performance Characterisation with different Feedstocks (M1-M28)
T3.2 Characterisation of Microbial Biofilm Symbioses (M1-M36)
T3.3 Metabolic Characterisation and Engineering (M2-M42)
T3.4 Cellular Component Evaluation Report (M42-M48)

WP4 (SO4): Integration (Modelling, Informatics, VR) and Final Design is established through a baseline BES performance model that incorporates:

i) Electrical/metabolic/genetic data of microbial components to integrate cell performance with digital modelling tasks (+VR).
ii) Characterises bioelectricity production.
iii) Characterises component assembly.
iv) Enables the development of descriptors and prototypes that embody these logics.
v) Creates recommendations for staged implementation of Mi-Hy.
vi) Achieves final design specification**,** which is the most time and resource intensive stage in the project.

T4.1 Baseline Model (M3-M12)
T4.2 Microbial Data Characterisation (M6–M28)
T4.3 Characterisation of Light Exposure (M12-28)
T4.4 Integration Prototyping (M18–M42)
T4.5 Powering MECs and LEDs (M28–M42).
T4.6 Review of Developments (M18-M42)
T4.7 Final Design Optimization for Citizen Science (M18-M28).

T4.8 Modelling Report (M36-M46).

WP5 Dissemination, Communicaiton, Exploitation and Public Installation

T5.1 Project Website (M1-M6)
T5.2 Communications Strategy and Impact Plan (CSIP) (M1–M8)
T5.3 Virtual Laboratory (M1-M10)
T5.4 Dissemination Activities (M6–M48)
T5.5 Training and Exploitation Activities (M6–M48)
T5.6 Communication Activities (M6–M48)
T5.7 Engaging key communities (M12-48):
T5.8 White Paper (M24–M48)

WP6 Project Management and Coordination

T6.1 Network Kick-off Meeting [NKM] (M1)
T6.2 General Project Management and Coordination (M1-48)
T6.3 Instalment of Steering Committee (M4)
T6.4 Portfolio Implementation Strategic Plan (M6)
T6.5 Data Management Plan (DMP) (M1–M6)
T6.6 Final DMP (M30–M48)

WP7 Portfolio Activities

T7.1 Report on Portfolio Collaboration Activities (M12)
T7.2 Updated Report on Portfolio Collaboration Activities (M24)
T7.3 Updated Report on Portfolio Collaboration Activities (M36)
T7.4 Final Report on Portfolio Collaboration Activities (M48)
T7.5 Joint Portfolio Report on Technologies Potential (M24)
T7.6 Updated Joint Portfolio Report on Technologies potential (M48)

1.2 Project Deliverables

Table 3: Overview of the deliverables within the Mi-Hy project.

Deliverable	Deliverable Name	Number	WP	Lead	Type	Dissemination	Delivery
D5.1	Project Website	2	5	BFC	R	CO	M6
D6.1	Network Kick-off meeting Report	1	6	KUL	R	CO	M3
D6.2	Portfolio Implementation Strategic Plan	3	6	KUL	R	CO	M6
D6.3	Data Management Plan	4	6	KUL	R	CO	M6
D5.2	Communications Strategy and Impact Plan (CSIP)	5	5	BFC	R	CO	M6
D6.4	Virtual Lab Protocol	6	1	KUL	R	CO	M10
D6.8	RP1 Technical Scientific Report	6	6	KUL	R	CO	M12
D4.1	Baseline MFC Performance Specifications	7	4	SONY	R	CO	M12

D3.1	Database of Cellular Components	9	3	CSIC	OTHER	CO	M28
D1.1	Mi-Hy Prototypes Designs	10	1	SOTON	R	CO	M28
D1.2	Mi-Hy Citizen Science Version	11	1	SOTON	DEM	CO	M28
D5.3	International MFC Design competition and Maker Faire	12	5	BFC	OTHER	PU	M34
D1.3	Hardware Component Specifications Report	13	1	SOTON	R	CO	M36
D1.4	Mi-Hy Modelling Report	14	1	SOTON	R	CO	M36
D6.9	RP2 Technical Scientific Report	15	6	KUL	R	CO	M36
D6.5	Final Data Management Plan	23	6	KUL	R	CO	M36
D4.2	Bio-Electro-Chemical and Light Models	16	4	SONY	OTHER	CO	M40
D5.4	Public Installation	17	5	BFC	DEM	PU	M40
D4.3	Bioelectrical Specifications and Network Modelling	18	4	SONY	R	CO	M34
D2.1	Evaluation of a Prosthetic Rhizosphere Report	19	2	UWE	R	CO	M48
D3.2	Cellular Component Evaluation Report	20	3	CSIC	R	CO	M48
D5.5	Final Diss., Comms., and Exploitation Report	21	5	BFC	R	CO	M48
D5.7	Final Communications Report	33	5	BFC	R	CO	M48
D5.6	White Paper	22	5	BFC	R	CO	M48
D7.1	Report on Portfolio Collaboration Activities	24	7		R	CO	M12
D7.2	Updated Report on Portfolio Collaboration Activities	25	7	KUL	R	CO	M24
D7.3	Updated Report on Portfolio Collaboration Activities	26	7	KUL	R	CO	M36
D7.4	Final Report on Portfolio Collaboration Activities	27	7	KUL	R	CO	M48
D7.5	Joint Portfolio Report on Technologies Potential	29	7	KUL	R	CO	M24
D7.6	Technologies potentials assessment	30	7	KUL	R	CO	M48
D7.7	Updated Joint Portfolio Report on Technologies potential	28	7	KUL	R	CO	M48

2. Project Data

Detailed information about the origin, purpose, characteristics, and potential usefulness of project data are described in this section and summarized in Table 4.

2.1 Data Type

Types of data/research outputs include experimental laboratory data (images/microscopy, DNA sequences, chemical analysis reports, text files, calculations, adapted figures), algorithms/AI, digital model software, drawings, images (photographs), integration protocols (documents), video, CAD files (3D models), design-led research outputs (video, photographs), and research publications (DTP, text/image). All deliverables will require the generation of novel (i.e., new) data by consortium members through surveys, meta-analyses, and experiments.

Table 4: Overview of the Mi-Hy deliverable descriptors.

Deliverable	Deliverable Name	Descriptor
D5.1	Project Website	Design and implementation of project website infrastructure for updatable content including website and project logo information also with social media links
D6.1	Network Kick-off meeting Report	Written report of the Mi-Hy project kick-off meeting, covering the project background information, project purpose, project scope, project timeline, roles, responsibilities, and the next steps. The project will be deconstructed into its key constituents and discussed each in detail with team members.
D6.2	Portfolio Implementation Strategic Plan	Written report of the of Mi-Hy contributions to the Portfolio Implementation Strategic Plan to address the challenges of the Carbon dioxide and nitrogen management and valorisation portfolio and collaboratively plan for a future of innovation.
D6.3	Data Management Plan	Definition of the Data Management Plan (current document)
D5.2	Communications Strategy and Impact Plan (CSIP)	Definition of the Dissemination and Exploitation Plan. An overall vision for the project messaging within the different phases of the project is developed (D5.1) to engage the artist-in-residence & reach external audiences for the effective & ongoing dissemination & exploitation of results & develop the White Paper
D6.4	Virtual Lab Protocol	Communications & software protocols established for the facility of the virtual laboratory that combines the digital model & Zoom/Microsoft Teams communications networks.
D6.8	RP1 Technical Scientific Report	The draft agenda, list of participants and presentations to be delivered during the review meeting
D4.1	Baseline MFC Performance Specifications	A baseline BES (MFC + MEC) performance model that incorporates i) electrical/metabolic/genetic data of microbial components to integrate cell performance with digital modelling tasks (+VR); ii) Characterises bioelectricity production; iii) Characterises component assembly; iv) enables the development of descriptors & prototypes that embody these logics; v) enables recommendations for staged implementation of Mi-Hy; & vi) final design specification
D3.1	Database of Cellular Components	Database of Cellular Components is developed from the characterisation of mixed biofilms that are optimised from different aspects of the 3D disposition of the different cellular components &

		their physical interactions, namely: i) through their nutrients cross-feeding (e.g. exopolysaccharide & lipopolysaccharides production & composition); ii) their intercellular chemical communication (e.g. quorum sensing); & iii) electron transfer efficiency.
D1.1	Mi-Hy Prototypes Designs	Mi-Hy Prototype Designs aim to integrate the constituent units achieves a multi-functional device, whose primary design goal is to characterise the different parameters where the collective outputs of the units are more than the sum of the parts
D1.2	Mi-Hy Citizen Science Version	Mi-Hy Citizen Science Version is developed with natural biofilms to demonstrate different degrees of integration of the constituent units to achieve a multi-functional device. The primary design goal is to demonstrate the different parameters and outputs to non-specialist audiences and to enable them to use the different units to propose their own solutions - i.e. crowd sourcing innovative applications
D5.3	International MFC Design competition and Maker Faire	International MFC Design competition and 2x Maker Faires in EU locations are organised. These events demonstrate the consumer Mi-Hy prototypes & further adapt them to the needs of uptake communities. Leverage potential of tech influencers. Emphasise the relationship between food security, climate change & robust empowered communities.
D1.3	Hardware Component Specifications Report	Hardware Component Specifications Report includes reporting on T1.1 to T1.5: where T 1.1 Establishing MFC & MEC Unit Design; T1.2 Optimising Electrode Design; T1.3 Optimising Membrane Design; T1.4 Floating Electrodes to Alter Redox Potentials; and T1.5 Optimising Nutrient Recovery (MFC), Arrays, Networks & Biosynthesis (MEC).
D1.4	Mi-Hy Modelling Report	Mi-Hy Modelling Report details developments within T4.1 to 4.7 namely: T4.1 4.1 Baseline Model; T4.2 Microbial Data Characterisation; T4.3 Characterisation of Light Exposure; T4.4 Integration Prototyping (MIL); T4.5 Powering MECs & LEDs; T4.6 Review of Developments; and T4.7 Final Design Optimization for Citizen Science.
D6.9	RP2 Technical Scientific Report	The draft agenda, list of participants and presentations to be delivered during the review meeting.
D6.10	RP3 Technical Scientific Report	The draft agenda, list of participants and presentations to be delivered during the review meeting.
D6.5	Final Data Management Plan	The Final Data Management Plan is a formal document that describes the data management life cycle for the data to be collected, processed and/or generated by the Mi-Hy research project.
D4.2	Bio-Electro-Chemical and Light Models	Bio-Electro-Chemical & Light Models enable the relationship between light and electrochemistry to be established where the use of blue+red light also controls N metabolism as the enzyme Nitrate Reductase & its gene expression are inhibited, reducing protein biosynthesis so amino acids accumulate.
D5.4	Public Installation	A citizen-friendly demonstrator will be developed for installation within an international public venue on invitation as part of KUL's and BF's design repertoire e.g. Tallinn Architecture Biennale (Estonia), LABoral (Spain), Evoluon (Netherlands) etc.
D4.3	Bioelectrical Specifications and Network Modelling	To date no model exists that captures the necessary bio-electro-chemo relationships for accurate predictive modelling, so control-oriented bioelectrochemical mathematical models of MFCs and neural network models will be used in parallel or combined, where the specific choice & combinations will be established during the project. While standard 2D representations link power outputs to

		performance parameters Mi-Hy seeks to establish the foundations of a living platform with the possibility of gathering environmental spatial data by deploying MFC nodes & responses to local environment perturbations from the constituent microbial communities.
D2.1	Evaluation of a Prosthetic Rhizosphere Report	Evaluation of Prosthetic Rhizosphere will provide an assessment of the anaerobic sites for N-fixing bacteria so that all species, not just legumes, could be provided with N derived from atmospheric N, supplementing N from waste fed to MFCs & enabling control over the balance of N sources. The resulting interplay of pH & N responses (as NH_4^+ & NO_3^- ions are interconverted) provides information about nutrient uptake plant characteristics & the nitrifying bacteria, which can be linked to system monitoring & manipulation (by redox potentials). Finally, the C:N:P ratio is the most significant determinant of biomass production. This deliverable will establish the formal relationship between these parameters.
D3.2	Cellular Component Evaluation Report	Cellular Component Evaluation Report reports on activities T3.1 to T3.3 namely: T3.1 Selecting Microbial Strains & Performance Characterisation with different Feedstocks; T3.2 Characterisation of Microbial Biofilm Symbioses; and T3.3 Metabolic Characterisation & Engineering.
D5.5	Final Diss., Comms., and Exploitation Report	Final Dissemination Communications and Exploitation Report describes and evaluates the strategy to maximise the impact of the project, to increase its visibility, and to ensure that project outputs reach a wide audience of relevant stakeholders.
D5.7	Final Version of the Plan for Dissemination and Exploitation	Definition of the final Dissemination and Exploitation Plan will outline how research results will be shared with potential users - peers in the research field, industry, other commercial players, and policymakers and provide details as to how the results will be used for commercial purposes or in public policymaking.
D5.6	White Paper	The White Paper will provide a persuasive, authoritative, in-depth report on a Mi-Hy's capabilities. It will address specific needs and provide appropriate solutions in ways that explain and promote Mi-Hy's particular methodology as an advanced problem-solving guide for a non-specialist audience.
D7.1	Report on Portfolio Collaboration Activities	Report of portfolio collaboration activities targeting the transition to the market, and roadmap of future actions and synergies
D7.2	Updated Report on Portfolio Collaboration Activities	Updated report of collaboration activities targeting the transition to the market, and roadmap of future actions and synergies
D7.3	Updated Report on Portfolio Collaboration Activities	Updated report of collaboration activities targeting the transition to the market, and roadmap of future actions and synergies
D7.4	Final Report on Portfolio Collaboration Activities	Final Report of collaboration activities targeting the transition to the market, and roadmap of future actions and synergies.
D7.5	Joint Portfolio Report on Technologies Potential	Updated joint portfolio report on the key factors affecting the penetration of the proposed technologies in each market segment and the relative competitiveness of each solution in different end user applications.
D7.6	Technologies potentials assessment	Final joint portfolio report on the key factors affecting the penetration of the proposed technologies in each market segment and the relative competitiveness of each solution in different end user applications.
D7.7	Updated Joint Portfolio Report on Technologies potential	A joint portfolio report on the key factors affecting the penetration of the proposed technologies in each market segment and the relative competitiveness of each solution in different end user applications.

2.2 Relationship between data and project objectives

The main objective of project is to identify key factors for producing a prosthetic rhizosphere that metabolises waste streams (air, wastewater) in ways that optimise hydroponics performance. To reach this overarching objective, links have been established between deliverables for the SOs in the various WPs (see Table 2). In SO1 (WP1) BES Hardware Optimisation and Added Functionality will be achieved by optimising the BES components (MFC/MEC), which are characterised for integration in WP4. In SO2 (WP2): Hydroponics parameters will be characterised, namely i) the specific wavelength for N utilisation; ii) biofilm performance; iii) and data for the digital model will be collected (specific parameters include temperature, pH, lights, temperature, and many aspects of the nutrient solution such as electrical conductivity) (WP4). In SO3 (WP3): Cellular Characterisation and Biofilm Optimisation will be achieved by identifying the specific electroactive microbial components for MFC (prosthetic rhizosphere); ii) characterising metabolic components for MEC iii) testing the microbial data parameters for WP4 model. In SO4 (WP4): Integration (Modelling, Informatics, VR) and Final Design will be established through a baseline BES performance model that incorporates i) electrical/metabolic/genetic data of microbial components to integrate cell performance with digital modelling tasks (+VR); ii) Characterises bioelectricity production; iii) Characterises component assembly; iv) enables the development of descriptors and prototypes that embody these logics; v) enables recommendations for staged implementation of Mi-Hy; and vi) final design specification, which is the most time and resource intensive stage in the project. In general terms, the scientific results associated with various deliverables will feed into other deliverables, mainly modelling and simulation (e.g., D3.2 and feed into the design of D1.2 through D1.3 and into the final modelling of D4.4). Table 5 describes the origin of each dataset for each project deliverable and the links between these datasets and project objectives.

Table 5: Overview of the data/ datasets associated with deliverables within the Mi-Hy project, including their names, descriptions, origins, and links to project objectives.

Deliverable	Dataset Name	Dataset Description	Data origin	Link to project objectives
D5.1	Public_outputs	Photographs, video, animations, public datasheets	All partners	Communications activities WP5
D6.1	Network Kick-off meeting Report	No dataset		
D6.2	Portfolio Implementation Strategic Plan	No dataset		
D6.3	Data Management Plan	No dataset		
D5.2	Communications Strategy and Impact Plan (CSIP)	No dataset		
D6.4	Virtual Lab Protocol	No dataset		
D6.8	RP1 Technical Scientific Report	No dataset		
D4.1	Baseline_MFC_performance	Data that describes the operational performance of the BES including the Anode potential, Cathode potential, Current density, Power density, Internal	WP1	Validated data and protocols will be modelled and tested in

		resistance, Temperature, pH, Electrolyte conductivity, Biomass concentration, Oxygen concentration, Organic substrate concentration, Water level/ volume, External load resistance, Electrical power output, Electrode surface area, Total Cell voltage. Format: experimental laboratory data (chemical analysis reports, text files, calculations) and research publications (DTP, text/image)		WP4 (SONY)
D3.1	Cellular_Components	Data that incorporates species type, characterised via feedstock, chemical, metabolic and bio electrochemical data. Format: experimental laboratory data (images-microscopy/video/photographs, DNA sequences, chemical analysis reports, text files, calculations, and research publications (DTP, text/image).	WP3	"Living" Library of Cellular Characteristics (fungi, bacteria, blue-green algae, yeast) validated for modelling parameters (CSIC)
D1.1	Mi-Hy_Prototypes	Data that described a prototype of integrated MFC/MEC/hydroponics system. Format: experimental laboratory data (chemical analysis reports, text files, calculations, adapted figures), algorithms/AI, digital model software, drawings, images (photographs), integration protocols (documents), CAD files (3D models), and research publications (DTP, text/image).	WP1, WP2, WP3, WP4	Identify components form Mi-Hy prototype
D1.2	Mi-Hy Citizen Science Version	Data that outlines an optimised, IP free, low cost, easy-to-access and maintain MFC/MEC design for citizen engagement activities. Format: drawings, images (photographs/ video), integration protocols, CAD files (3D models), design-led and artistic research outputs and research publications (DTP, text/image).	WP1, WP5	Identify Mi-Hy components to increase public accessibility
D5.3	International MFC Design competition and Maker Faire	No dataset		
D1.3	Hardware_Components	Datasets that describe electrodes, materials, semi-permeable membrane, chassis specifications. Format: experimental laboratory data (images/ microscopy, DNA sequences, chemical analysis reports, text files, calculations, adapted figures), algorithms/AI, digital model software, CAD files (3D models) and research publications (DTP, text/image).	WP1	Validate final prototype specifications (SOTON)
D1.4	Modelling_Report	Dataset for integration of MFC parameters into Mi-Hy. Format: experimental laboratory data (images/ microscopy, DNA sequences, chemical analysis reports, text files, calculations, adapted figures), algorithms/AI, digital model software, CAD files (3D models), and research publications (DTP, text/image).	WP1, WP2, WP3, WP4	Identify components for Mi-Hy prototype
D6.9	RP2 Technical Scientific Report	No dataset		

D6.5	Final DMP	No dataset		
D4.2	BEC_Light_Models	Wavelength, photoperiod, intensity, BES variables, metabolic performance, environmental conditions. Format: experimental laboratory data (images/ microscopy, chemical analysis reports, text files, calculations, adapted figures), algorithms/AI, digital model software and research publications (DTP, text/image).	WP1, WP2, WP3	Validate variables for systems model
D5.4	Public Installation	No dataset		
D4.3	Bioelectrical_Network	Wavelength, photoperiod, intensity, BES variables, metabolic performance, environmental conditions. Format: experimental laboratory data (images/ microscopy, DNA sequences, chemical analysis reports, text files, calculations, adapted figures), algorithms/AI, digital model software, CAD files (3D models) and research publications (DTP, text/image).	WP1, WP2, WP3	Identify variables for Mi-Hy systems model
D2.1	Prosthetic_Rhizosphere Evaluation	Calculations, metanalyses. Format: experimental laboratory data (chemical analysis reports, text files, calculations, adapted figures), algorithms/AI and research publications (DTP, text/image).	WP1, WP2, WP3, WP4	Validate protocols for building Mi-Hy prototype
D3.2	Symbiotic_Components	Data describing specific symbioses characterised via chemical, metabolic and bio electrochemical data. Format: experimental laboratory data (images/ microscopy, DNA sequences, chemical analysis reports, text files, calculations, adapted figures), and research publications (DTP, text/image).	WP3	Validate Mi-Hy symbiotic species
D5.5	Final Diss., Comms., and Exploitation Report	No dataset		
D5.7	Final Communications Report	No dataset		
D5.6	White Paper	No dataset		
D6.5	Final Data Management Plan	No dataset		
D7.1	Report on Portfolio Collaboration Activities	No dataset		
D7.2	Updated Report on Portfolio Collaboration Activities	No dataset		
D7.3	Updated Report on Portfolio Collaboration Activities	No dataset		
D7.4	Final Report on Portfolio Collaboration Activities	No dataset		
D7.5	Joint Portfolio Report on Technologies Potential	No dataset		
D7.6	Technologies aAssessment potential	No dataset		
D7.7	Updated Joint Portfolio Report on Technologies potential	No dataset		

2.3 Data Characteristics

In the Mi-Hy project, different types of data will be stored in different file formats. All datasets will be exclusively in digital formats and will be created throughout the project as the result of experimental studies. These digital datasets will be stored in a variety of formats and will have volumes ranging from less than 1GB to greater than 50TB.

Table 6: Specific characteristics of the data/ datasets of the Mi-Hy project, including their anticipated types, formats, and volumes.

Deliverable	Dataset Name	Data Type	Format	Volume
D5.1	Public_outputs	communications	MP4, MOV, pdf, jpg, TIFF, PSD, png, Word, DWG, VRML	< 50TB
D4.1	Baseline_MFC_performance	experimental	Xls, odf, png, jpg	<1GB
D3.1	Cellular_Components	experimental	Xls, odf, png, jpg, png,	<1GB
D1.1	Mi-Hy_Prototypes	aggregate	Physical models, CAD, Xls, odf, png, jpg	<50TB
D1.2	Mi-Hy Citizen Science Version	aggregate	Physical models, CAD, Xls, odf, png, jpg	<50TB
D1.3	Hardware_Components	experimental	Physical models, CAD, Xls, odf, png, jpg	<50TB
D1.4	Modelling_Report	aggregate	Physical models, CAD, Xls, odf, png, jpg	<50TB
D4.2	BEC_Light_Models	experimental	Xls, odf, png, jpg, png,	<1GB
D4.3	Bioelectrical_Network	experimental	Xls, odf, png, jpg, png,	<1GB
D2.1	Prosthetic_Rhizosphere Evaluation	experimental	Xls, odf, png, jpg, png,	<1GB
D3.2	Symbiotic_Components	experimental	Xls, odf, png, jpg, png,	<1GB

2.4 External Usefulness of data

The data and knowledge produced through this project should provide guidance for the incorporation of microbial technologies into hydroponics to generate more efficient C and N synthesis. Building on the natural cycles of C and N, Mi-Hy intensifies these processes, making them accessible to further technological intervention while working within the carrying capacity of the site. Providing a productive platform for new forms of biosynthesis it extends the frontiers of the contributing fields (synthetic biology, hydroponics, environmental engineering, microbial electro-technologies, sustainable architectural design, ICT/informatics, bio/electrochemistry) whereby global development takes place while potential challenges in one aspect of the platform do not compromise advances in another. The value of integrating microbial sources of energy in addition to renewables aims to generate an overall more resilient hydroponics system with increasing degrees of autonomy and self-regulation within different territories of the overall system so it is much harder to reach tipping points, and consequent system collapse. As both passive and active hydroponics systems depend on electricity to power the different components such as grow lights, water pumps, aerators, fans, etc., integrating MFCs to power LEDs and add new functionality through MES electrobiosynthesis enables a higher level of outputs than growing plants traditionally with additional synthesis of novel biomolecules. To maintain a carefully controlled growing environment, system components (lights, temperature, and many aspects of the nutrient solution such as pH and electrical conductivity) are integrated with 'microbial intelligence,' a uniquely environmental sensitivity, which is expressed as the total bioelectricity produced at any given moment to engage an AI/Machine Learning set-up that models the system, enabling it to be stabilized via automation. MFCs will also be explored as a microbial 'buffer' (or immune) system to remove potential pathogens, as waterborne diseases are considerably higher in hydroponics systems. The system advances its circularity to develop a material/product extension of Mi-Hy through prototyping a new type of "green" bio-brick building material for recycling C and D waste in urban environments. Due this broad range of potential audiences for the project's data and results, findings will be communicated via different channels such as scientific literature, conferences, the project website, industry/professional press, social media, and newsletters. Explicitly scientific data, such as materials and methods, protocols, and coding scripts, will be available online in trusted repositories as part of related scientific publications, making it possible for other researchers to not only better understand the underlying methodologies used to deliver the project's findings, but also, when possible, to replicate the findings themselves. The Mi-Hy consortium will make its datasets Open Access and upload them to the Project Website and to Zenodo, the Open Science platform funded by the EU, the Open Hardware Observatory to assure a unique DOI for each dataset, unless the institution of the primary creator of the relevant publication/data recommends a specific repository. After IP protection has been assessed/secured, useful open access datasets will also be publicly available on the Project Website and made available for download. Open Research Data is managed via a detailed Data Management Plan (DMP) in compliance with Article 17 to ensure that data collected throughout the project, and underpinning the publications, can be accessed (and therefore the results reproduced) and that the data/research outputs are findable, accessible, interoperable, and reusable (FAIR). For Open Access scientific publications, we will use public shared spaces e.g., arXiv.org. For green open access Lirias is used. Other project outputs e.g., video, animations, public information are hosted on the Mi-Hy website, the Research Catalogue (www.researchcatalogue.net) and YouTube.

3. FAIR data

The project consortium aims to make all data, aside from any GDPR-sensitive data and data obtained within the confines of a confidentiality agreement. Open Research Data is managed via this detailed Data Management Plan (DMP) and its rolling updates, in compliance with Article 17 to ensure that data collected throughout the project, and underpinning the publications, can be accessed (and therefore the results reproduced) and that the data/research outputs are findable, accessible, interoperable, and reusable (FAIR)[1].

3.1 Findability

The Mi-Hy consortium will make its datasets Open Access and upload them to the Project Website and to Zenodo, the Open Science platform funded by the EU, the Open Hardware Observatory, to assure a unique DOI for each dataset, unless the institution of the primary creator of the relevant publication/data recommends a specific repository. After IP protection has been assessed/secured, useful open access datasets will also be publicly available on the Project Website and made available for download.

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3.1.1 Persistent Identifiers

All data and research outputs will be evaluated by the board before making datasets open. For Open Access scientific publications, we will use public shared spaces e.g., arXiv.org. For green open access Lirias is used. Other project outputs e.g., video, animations, public information are hosted on the Mi-Hy website, the Research Catalogue (www.researchcatalogue.net) and YouTube. The consortium foresees a maximum 6-month period during which IP protection will be assessed/secured. The accessibility of research output also follows the publication strategy of the partners. The Periodic Reports will include an update of the datasets that have been produced during the given period and their accessibility status. After the IP concerns have been addressed (non-GDPR sensitive and unbound by confidentiality agreements), datasets will be publicly available, as discussed above. Datasets that are used in scientific publications or used to train Mi-Hy's published machine learning algorithms will be given DOI and made publicly available, being deposited in online trusted repositories such as Zenodo, with programming code deposited in GitHub and/or GitLab. Zenodo automatically assigns a persistent identifier (DOI) to all inputs, and the GitHub and GitLab repositories will be linked within the appropriate Zenodo repositories. KUL's institutional repository RDR (https://rdr.kuleuven.be) will be used to ensure that all data has a DOI and metadata can be added so it is findable. If open access is not possible, reasons for restricted data sharing for datasets will be given.

[1] Mark D. Wilkinson; Michel Dumontier; IJsbrand Jan Aalbersberg; et al. (15 March 2016). "The FAIR Guiding Principles for scientific data management and stewardship". Scientific Data. 3 (1): 160018. doi:10.1038/SDATA.2016.18

3.1.2 Metadata, searchability, and indexing

Data deposited in Zenodo will always be described with metadata and is compliant with DataCite, a leading global non-profit organization that provides persistent identifiers (specifically DOIs) for research data and other research outputs. The ISA framework will be used for metadata in combination with the metadata standard for the field of inquiry. Specifically, the metadata will always include the persistent identifier of the data it is related to, and the metadata of each deposit will be indexed and searchable after publishing in Zenodo's search engine. The data will be stored in open non-proprietary formats such as (JPEG/PNG/TIFF, PDF, JSON, CSV, RDF). If proprietary formats are used internally, a usable copy will be available in one of the recommended open formats. As Mi-Hy will link data from different fields into a common modelling system, the consortium may need to introduce new metadata. Data sharing and transfer within the consortium either goes through a protected server storage managed by the consortium (for non-real-time data exchange) or over encrypted channels (VPN, SSH tunnel) for real-time data. Finally, all relevant materials will be directed to DataCite servers during DOI registration and indexed therein. Zenodo automatically catalogues the metadata, with relevant statistics reported, such that the data and metadata can be seamlessly harvested through the platform. Additionally, the metadata will (whenever possible) contain the following: (i) the terms "European Union (EU)", "European Innovation Council (EIC)" and "Carbon Dioxide and Nitrogen Valorisation and Management Pathfinder Challenges"; (ii) "Microbial Hydroponics" (name of the project); (iii) "Mi-Hy" (the project acronym); (iv) "101114746 " (the project/grant number); (v) the publication date in case of a scientific publication or the date it is deposited in the repository; (vi) the PID (*i.e.*, DOI), which is automatically assigned when using Zenodo.

3.2 Accessibility

3.2.1 Trusted repositories

All data generated and/or collected through the project that can be made publicly available (*i.e.*, non-GDPR sensitive data and unbound to confidentiality agreements) will be deposited online in a trusted repository. The main repositories that will be used are Zenodo for the general content and GitHub and GitLab for programming code (*e.g.*, written in R). Data entered in GitHub/GitLab will be linked to Zenodo. All open access data in the repositories will by licensed through CC-BY, CC-0, or an equivalent license. Publications generated using project data will be deposited in a trusted repository at the time of publication. All information required for the understanding, reuse, or repurposing of the data will be attached to the data, and all information necessary to repeat, recreate, and validate the results will accompany the publications. In the repository, immediate open access will be provided. Data containing GDPR-sensitive information and data obtained through confidentiality agreements will not be made publicly available, and when reports or scientific papers are written using processed, pseudonymized, and/or anonymized data, open access will be granted through a trusted repository.

3.2.2 Arrangements with repositories

Detailed information is provided on Zenodo's website, and it was therefore ensured that this repository will meet the needs of the project prior to the formulation of this DMP. Specifically, Zenodo allows the deposit of all data formats, and the default limit for total file size per deposit is 50GB. Although, at this stage of the project, there is some indication that some datasets may exceed this size (specifically image files), it has been indicated by Zenodo that if more volume is needed, it can be requested. Zenodo also makes research results citable and, through OpenAIRE, integrates them into the existing reporting lines of the European Commission, with uploading of the research content free of charge. For programming code, such as R codes and scripts, GitHub/GitLab will be used, which are trusted repositories specifically tailored to the collaborative development of these types of documents. These repositories enable the archiving of hosted repositories within Zenodo, not only making it easier to refer to and find the desired GitHub/GitLab repository, but also creating a persistent identifier. Additionally, GitHub/GitLab are free-to-use and provide 500MB storage, which should be more than sufficient for the programming code, scripts, *etc*. that will be developed within this project.

3.2.3 Identifiers assigned through repositories.

Data deposited into Zenodo will automatically receive a PID (*i.e.*, DOI), and Zenodo allows DOI versioning, which will allow the referencing across different versions of a document or data. Research outputs (*i.e.*, R scripts, programming code, *etc*.) and data deposited into GitHub/GitLab will be assigned a PID (*i.e.*, DOI) through the linking of the GitHub/GitLab repository to an associated Zenodo repository.

3.2.4 Open availability of Data

GDPR-sensitive and data collected within the bounds of a confidentiality agreement, which may include names, addresses, locations, email addresses, and/or recordings that cannot be made publicly available are not foreseen, however, if such data (e.g. questionnaires from exhibition surveys) are collected they will not be made publicly available. In the case of both the GDPR-sensitive and any potential confidentiality-bound data, those raw data will be processed into a pseudonymized or anonymized form, and once processed, will be included in reports or publications. The processed data will ensure anonymity and therefore may be made available via an online trusted repository, as previously described.

3.2.5 Data storage and access to Sensitive Data

Data and research outputs will be stored within the institutional servers of the individual partners, and data that is GDPR sensitive or obtained through confidentiality agreements will stay there in a safe, enclosed environment only allowing access to the persons directly involved in that specific part of the deliverable. In the case that a participant gives permission to the researchers to share personal information with other partners or research projects, this will be documented through the signing of an informed consent document, but without this signed consent document, sensitive data will not be made publicly available and will not be shared with other project partners. Data that can be shared openly among the project partners will be placed on the project SharePoint, with access restricted to only those actively involved in the project, with access controlled by the project management team based at KUL.

3.2.6 Availability of metadata

All metadata will be openly available in the previously described repositories and will be licensed through a CC-0 waiver. Zenodo allows the harvesting of data from the repository through its OAI-PMH protocol. Additionally, data will be exported in several standard formats, such as MARCXML, Dublin Core, and DataCite Metadata Schema.

3.2.7 Duration

Data or metadata should be deposited in repositories (see above) and made publicly available as soon as possible, provided they are not GDPR sensitive, obtained through confidentiality agreements or subjected to patenting. All results will be evaluated by the board before making datasets open. The consortium foresees a maximum 6-month period during which IP protection will be assessed/secured. The accessibility of research output also follows the publication strategy of the partners. The Periodic Reports will include an update of the datasets that have been produced during the given period and their accessibility status. After the IP concerns have been addressed, datasets will be publicly available, as discussed above. Datasets that are used in scientific publications or used to train Mi-Hy's published machine learning algorithms will be given DOI and made publicly available. KUL's institutional repository RDR will be used to ensure that all data has a DOI and metadata can be added so it is findable. If open access is not possible, reasons for restricted data sharing for datasets will be given. The (meta) data will be retained as long as possible provided the repository remains active, this will be far beyond the end of the Mi-Hy project, ensuring these data remain available to the scientific community for the years to come.

3.2.8 Additional documentation and software

Whenever possible, free-to-use software will be used to ensure data accessibility and readability.

Table 3 presents an overview of the GDPR sensitivity of the datasets, their storage locations, persistent identifiers, and to what extent the datasets will be publicly available. Note that in some WPs and deliverables, the precise method to be used has yet to be decided, and therefore the GDPR-sensitivity described may still change.

Table 7. Overview of the datasets within the Mi-Hy project, the GDPR sensitivity of the datasets, their storage locations, persistent identifiers, and to what extent the datasets will be publicly available.

Deliverable/ ID	**Data/set Name**	GDPR Sensitivity	Storage Location	Persistent Identifier	Access Level
D5.1	Public_outputs	No	KUL Sharepoint, institutional servers	DOI	CO
D6.1	Network Kick-off meeting Report	No	KUL Sharepoint, institutional servers	DOI	CO
D6.2	Portfolio Implementation Strategic Plan	No	KUL Sharepoint, institutional servers	DOI	CO
D6.3	Data Management Plan	No	KUL Sharepoint, institutional servers	DOI	CO
D5.2	Communications Strategy and Impact Plan (CSIP)	No	KUL Sharepoint, institutional servers	DOI	CO
D6.4	Virtual Lab Protocol	No	KUL Sharepoint, institutional servers	DOI	CO
D6.8	RP1 Technical Scientific Report	No	KUL Sharepoint, institutional servers	DOI	CO
D4.1	Baseline_MFC_performance	No	Institutional servers (SOTON)	DOI	CO
D3.1	Cellular_Components	No	Institutional servers (CSIC)	DOI	CO
D1.1	Mi-Hy_Prototypes	No	KUL Sharepoint, institutional servers	DOI	CO
D1.2	Mi-Hy Citizen Science Version	No	Institutional Servers (SOTON, BFC)	DOI	CO
D5.3	International MFC Design competition and Maker Faire	No	Institutional Servers (BFC)	DOI	PU
D1.3	Hardware_Components	No	Insitutional Servers (SOTON)	DOI	CO
D1.4	Modelling_Report	No	KUL Sharepoint, institutional servers	DOI	CO
D6.9	RP2 Technical Scientific Report	No	KUL Sharepoint, institutional servers	DOI	CO
D6.5	Final DMP	No	KUL Sharepoint, institutional servers	DOI	CO
D4.2	BEC_Light_Models	No	Institutional	DOI	CO

			Servers (SONY)		
D5.4	Public Installation	No	N/A	DOI	PU
D4.3	Bioelectrical_Network	No	Institutional servers (SONY)	DOI	CO
D2.1	Prosthetic_Rhizosphere Evaluation	No	Instituitional servers (UWE)	DOI	CO
D3.2	Symbiotic_Components	No	Institional Servers (CSIC)	DOI	CO
D5.5	Final Diss., Comms., and Exploitation Report	No	KUL Sharepoint, institutional servers	DOI	PU
D5.7	Final Communications Report	No	KUL Sharepoint, institutional servers	DOI	CO
D5.6	White Paper	No	KUL Sharepoint, institutional servers	DOI	CO
D6.5	Final Data Management Plan	No	KUL Sharepoint, institutional servers	DOI	CO
D7.1	Report on Portfolio Collaboration Activities	No	KUL Sharepoint, institutional servers	DOI	CO
D7.2	Updated Report on Portfolio Collaboration Activities	No	KUL Sharepoint, institutional servers	DOI	CO
D7.3	Updated Report on Portfolio Collaboration Activities	No	KUL Sharepoint, institutional servers	DOI	CO
D7.4	Final Report on Portfolio Collaboration Activities	No	KUL Sharepoint, institutional servers	DOI	CO
D7.5	Joint Portfolio Report on Technologies Potential	No	KUL Sharepoint, institutional servers	DOI	CO
D7.7	Updated Joint Portfolio Report on Technologies potential	No	KUL Sharepoint, institutional servers	DOI	CO

3.3 Interoperability

The exchange of data among researchers will be facilitated by a reliance on interoperable formats, such as those supported by Microsoft Excel and Microsoft Word, whenever possible. Similarly, for statistical analyses, programming scripts, *etc.*, free-to-use software, such as R, will be used. The data will be stored in open non-proprietary formats such as (JPEG/PNG/TIFF, PDF, JSON, CSV, RDF). The DMP will list the recommended open data formats for each of the research fields of the consortium. If proprietary formats are used internally, a usable copy will be available in one of the recommended open formats. The ISA framework will be used for metadata in combination with the metadata standard for the field of inquiry. The list of standards will be listed in the DMP in collaboration with all the partners and reviewed annually to ensure all published datasets are up to date with the latest developments. As Mi-Hy will link data from different fields into a common modelling system, the consortium may need to introduce new metadata. Data sharing and transfer within the consortium either goes through a protected server storage managed by the consortium (for non-real-time data exchange) or over encrypted channels (VPN, SSH tunnel) for real-time data. Additionally, vocabulary will be standardized, whenever possible, with the following formats consistently applied across project datasets: (i) dates will be reported in "yyyy/mm/dd" format; European countries will be reported either in full according to the UN Geoscheme or abbreviated according to the official Eurostat abbreviations; bacteria will be reported with full genus and species in italic and serotypes in Latin, with any abbreviations to genus clearly described; viruses will be reported using official scientific names, with strain-specific information in brackets, if necessary.

3.4 Reusability

Mi-Hy uses transparent research design, robust statistical analyses, addresses negative results early and shares through preregistration and preprints, with open access to software, workflows, tools, etc.

3.4.1 Additional documentation

All datasets, programming scripts, *etc.* will always contain a README file and/or a list of abbreviations to ensure clarity. Mi-Hy will make use of Open Licenses for data sharing and re-use including the Creative Commons licence for images, text, and design files and Open Data Commons for datasets. Software modules will, as much as possible, be made accessible under Open-Source licenses (LGPLv3…) through code repositories e.g., Github and easy-to-use tools such as JupyterLab (www.jupyter.org). We will assure that the structure of public datasets is documented (in case they are not stored using standard formats and metadata) and provide Open-Sourced example code to import the data for re-use.

3.2.4 Public domain

Partners that have produced data through the project workflow will remain the owners of that data but will share the raw data, and, if applicable, the post-treated data, and/or overall findings and conclusions with project management team and, if asked, with other partners. All outputs or processed data produced through the project workflow that are neither confidential nor GDPR sensitive will be made publicly available as licensed under CC-BY or an equivalent/comparable license, with metadata licensed under CC-0, as is automatically done when using Zenodo.

3.4.3 Third party use

Research output available through trusted repositories can be used by other parties, if correctly referenced. During the project, surveys/interviews will be conducted, and participants will have to sign an informed consent document. If participants agree that the content of their completed survey/interview can be transferred to other research projects and institutions, with or without their contact details, this output can also be used by other third parties upon request.

3.4.4 Quality assurance process

The Mi-Hy consortium is comprised of researchers from internationally recognized institutes with their own institution-specific research standards. Each Project Lead is responsible for data management and quality assurance within their own organisation using their own data management systems, where costs are included in their respective budgets. The project partners will organise shared data according to specifications identified in the DMP by M6. SONY, in collaboration with coordinator KUL, will assure the availability and quality of the public datasets of the consortium as part of the digital modelling tasks. Additionally, research outputs, including non-sensitive data, generated through the project workflow will be shared across institutions and partners, with this sharing serving as an implicit peer review system prior to explicit peer review at the time of publication or wider distribution. The protocols, procedures, and methodologies used to collect data are discussed in regularly scheduled cross-deliverable and cross-WP meetings to get input, feedback, and assure the applicability, relevance and quality of the data collected. Finally, when deliverables are drafted, the complete document is reviewed by at least two other partners in the consortium prior to the submission of the deliverable to the EC and/or peer-reviewed journal.

4. Other Outputs

Due to the broad range of potential audiences for the project's data and results, findings will be communicated through varied channels and networks, such as through peer-reviewed scientific literature, conference abstracts, posters, and presentations, the project website, industry/professional press, social media, and newsletters.

5. Resource Allocation

5.1 Costs

There are no cost anticipated, at this stage of the project, associated with the use of trusted repositories to meet FAIR data guidelines. At the deliverable level, the data and information will be stored on institutional servers at no charge. Each institution stores their research data on local secure networks and server, or protected cloud storage systems, with a daily regular full backup. The actual deposition of project data into the repositories is free up to 50GB per record for Zenodo and for up to 500MB per user for GitHub/GitLab, which is considered likely to be enough space for the data generated in the project.

5.2 Responsibilities

The overarching data management within the Mi-Hy project is led by KUL, the project coordinator. KUL's institutional repository RDR will be used to ensure that all data has a DOI and metadata can be added so it is findable. If open access is not possible, reasons for restricted data sharing for datasets will be given. At the deliverable level, each consortium partner institution is responsible for the handling and storing of data collected through the project workflow, meaning partners are responsible for ensuring data confidentiality and storage, including the provision of back-ups on institutional servers, hard drives, computers, *etc*.

5.3 Duration

The data management team at KUL will ensure preservation of the data deposited at the project SharePoint for at least 5 years after the end of the project, at which point, archiving responsibilities will rest upon the partners that generated the data. Data and research outputs deposited into Zenodo will be preserved for at least five years. Research articles published in open access journals should remain accessible indefinitely through online libraries and search platforms.

6. Security

Collected data and research outputs will be stored, with back-ups, on institutional servers, hard drives, computers, *etc*., with individual partners adhering to institution-level information technology security protocols and policy. Sensitive data will remain with the institution that collected that data, stored in a pseudonymized such that personally identifiable data cannot be identified within a single document. Only researchers within the specific group working on the sensitive data will have access, unless written and documented consent has been given by the person(s) whose data generated the dataset. Sensitive data will not be shared or transferred among partners unless the participant gave its informed consent to do so, and in the absence of this consent, only anonymized data will be shared among partners.

6.1 Data sharing and transfer within the Mi-Hy Consortium

Data sharing and transfer within the consortium either goes through a protected server storage managed by the consortium (for non-real-time data exchange) or over encrypted channels (VPN, SSH tunnel) for real-time data. Data sharing and transfer within the consortium occurs via secure methods of digital transfer through password protected access by named members of the consortium. Data from microbial intelligence experiments by SOTON is securely transferred to SONY with encrypted protection and incorporated into the digital model. The digital model and Zoom communications networks that combined, comprise the facility of the virtual laboratory, are used concurrently by consortium members but are not directly connected. This maintains the separation between the digital model and Zoom platform. When open access is not possible, reasons for restricted data sharing for datasets will be given.

7. Ethics

The beneficiaries of Mi-Hy will respect and uphold the fundamental principle of research integrity as set out in the European Code of Conduct for Research Integrity (European Code of Conduct for Research Integrity of ALLEA (All European Academies). Specifically, the Mi-Hy consortium will comply with the following principles: i) reliability in ensuring the quality of research reflected in the design, the methodology, the analysis, and the use of resources; ii) honesty in developing, undertaking, reviewing, reporting, and communicating research in a transparent, fair, and unbiased way. All beneficiaries will ensure that persons carrying out research tasks follow the good research practices including ensuring, where possible, openness, reproducibility and traceability and refrain from the research integrity violations described in the Code.

The beneficiaries will obtain all approvals or other mandatory documents needed before starting any action task raising ethical issues, notably from the (national or local) ethics committee or other bodies such as data protection authorities. These documents will be kept on file and be submitted upon request by the coordinator to the granting authority. If they are not in English, they will be submitted together with an English summary, which shows that the documents cover the action tasks in question and includes the conclusions of the committee or authority concerned (if any).

For Mi-Hy four specific ethical issues were identified on screening:

- **Human cells / tissues**
- **Non-EU countries**
- **Environment, health, and safety**
- **Artificial intelligence**

4.1 Ethical Dimension of the Objectives, Methodology and Likely Impact

Human cells/ tissues

Legally, human tissue includes anything derived from a human being so the use of Urine in MFCs requires ethical consideration. The MFC technology has had approval from the National Health Service Research Ethics Committee (NHS REC, approval no. 12/ YH/0493), following rigorous ethical assessment. After the completion of regular inspection/audit for two years, the NHS acknowledged that this work complies fully with NHS ethical regulations and no longer requires NHS oversight (letter sent by NHS REC on August 10, 2015, can be provided upon request). This work has since been continuously subject to local (previously at UWE, presently at SOTON) Ethical scrutiny, providing comprehensive Risk Assessment documents for new research activities. These include new research projects, new trials, new public exhibition events at different locations, and has consistently followed the Health and Safety regulations of those venues, at which previous projects Urine-tricity, LIAR and ALICE have been showcased, including Glastonbury Music Festival, UK (2015 onwards) and Beijing Toilet Technology Showcase (November 2018). While these rigorous UK protocols have been followed, following the Brexit referendum these protocols will be updated to ensure compliance with EU standards, policies, and practices. We aim to uphold regulatory compliance in always keeping with the appropriate EU regulations and guidelines.

Non-EU countries

Status: Both UWE and SOTON are in the UK. Following the Brexit referendum, the UK is no longer obliged to follow regulatory alignment with the EU or uphold EU Law. This creates the possibility of UK divergence from EU regulatory standards. The University of Southampton (SOTON) is in the United Kingdom and are Project Leaders for WP1 which contains the integrative tasks of the projects where BES hardware and microbial elements come together through organic scaffoldings, bioelectrical system (BES) hardware (MFC) and digital models to produce the final demonstrator that proves the principle of the project. SOTON will also provide the MFCs to the whole consortium for the hydroponics cultivation chamber set-ups (CSIC, SONY for experimental study and BF, KUL for public engagement). The University of the West of England (UWE) is Project Leader for WP2 which contains the hydroponics tasks of the projects. This will be conducted at the Envirotron greenhouse, which features LED lighting that minimises environmental impact and affords exquisite control of light, enabling researchers to simulate and experiment with a wide range of conditions. Compartments are independently fully climate controllable. No research activities are carried out in these organisations that are prohibited in the EU. All activities will comply with the ethics provisions set out in the Grant Agreement, will uphold the highest ethical standards and will be applicable to international, EU and national law.

Environment Health and Safety

Mi-Hy addresses nitrogen and carbon metabolism through the study of limited waste stream use and via genetically modified organisms. Consequently, there is a small risk that activities may adversely affect the environment through: i) the handling of wastestreams with high nitrogen, phosphorous and carbon loads, which on build up in lakes, rivers, streams, *and* coastal areas, result in serious environmental, economic, *and health effects*; and ii) the use of synthetic biology with the risk of enhanced pathogenicity of workhorse organisms with the emergence of a new disease, pest or weed with adverse effects on species, communities, or ecosystems. Additionally, the health and safety of all human participants is a priority in Mi-Hy whether participants are subjects, investigators, or uninvolved third parties. The Mi-Hy consortium therefore adopts the precautionary principle upholding legislation on pollution control and health and security, working with strict laboratory protocols and practices when using residues from wastestreams and modified organisms.

Artificial Intelligence

The 'artificial intelligence' indicated in this study (WP4, activities) is developed to study the behaviour of microbes and generate data for the digital twin, which helps integrate the microbial electronic components by making predictive evaluations of their electronic performance and compatibility with other microbial electronic elements.

We have taken all possible precautions for unbiased AI, and in particular we are not using an AI that may be used to classify human behaviour. The data to train the AI will be derived from in vitro microbial experiments described in WP4. Understanding microbial behaviour for the digital twin through use of an AI *at system level* not only helps understand microbial behaviour but also to understand microbial intelligence and (importantly) enact on this with appropriate action. For example, using a network of MFCs as early warning devices for the detection of harmful substances into our environment, and having the hydraulic control valves connected to the action-selection/decision module, so that they can be accordingly turned OFF to stop the inflow of toxicants. Equally we could be utilising AI to respond to extreme pH or temperature changes, via feedback loops, and allowing tools in our system to combat the shift to any extreme.

Integration between data and microbes will be enabled by different modes of information (state variables, potentially in combination), new parameters (chemical, bio, cellular), metrics, optimised energy consumption, and information processing across a range of timescales, enable enough system control to direct decision-making and for monitoring the performance of organic electronics. The impact of these activities is for the compilation and development of the microbial components only and is not foreseen to have any negative impact on humans or the environment. Specifically, the AI proposed in the project is not used to analyse personal data or any data that stem in any way from human activities. It is also not used in any way to classify personal data or human activities. The data that is generated comes from both inorganic sensors and from microbial systems used as a sensor. The data is combined by the AI to steer high-level functions and actuators. As such, it is an advanced, system-level component used in a classical control theory approach. We therefore believe that the use of the proposed AI does not raise ethical concerns related to human rights and values.

4.2 Compliance with Ethical Principles and Relevant Legislations

Use of Urine in MFCs

Following the Brexit referendum, the health and safety protocols developed for SOTON's MFCs will be updated to ensure compliance with all relevant EU regulations. All activities will comply with the ethics provisions set out in the Grant Agreement, and notably adopt the highest ethical standards as well as the appropriate applicable international, EU and national law (in particular, EU Directive 2004/23 on standards for the donation, procurement, testing, processing, preservation, storage and distribution of human tissues and cells). In Mi-Hy a limited amount of urine will be used by SOTON, who will keep track of the origin of the collected urine and obtain the necessary accreditation for collecting the urine, with free and fully informed consent of the donors. When a limited amount of urine is required to inoculate the MFC stack, this is safely taken from a local activated sludge tank in the secondary treatment stage of wastewater treatment plants. This means that the urine/wastewater has already been screened for pathogens and is therefore safe to use, always with caution complying with local HandS governance and wearing Personal Protective Equipment (PPE). The waste stream is like domestic toilet waste, so is always treated with appropriate care. The sludge waste can be disposed down the normal drain or sluice, which connects directly to sewerage, and this should be done with copious amounts of water so that there is high dilution. Mixing the sludge waste with a disinfectant like Virkon® for 20 minutes (25g in 5L) and then pouring down the drain provides an additional level of biosecurity. Other than SOTON, all hydroponic cultivation chambers will use synthetic urine (rather than collected urine/wastewater) which contains tryptone (or peptone), yeast extract, NaCl and urea.

Non-EU countries

Both UWE and SOTON are UK based. Following Brexit on 1st January 2021, parcels to Europe are subject to customs and duty fees. This means that goods shipped between EU countries and the UK mainland must clear customs and require a commercial invoice and other export documentation. This will be considered in the planning, preparation, and completion of all MFC deliverables provided by SOTON to SONY, CSIC, KUL, BFC. Risks associated with regulatory divergence will be addressed by complying with the ethics provisions set out in the Grant Agreement, and notably: i) highest ethical standards; and ii) applicable international, EU and national law.

Environment Health and Safety

Mi-Hy adopts the highest ethical standards and safety procedures for the handling of all microorganisms. All hydroponics experiments will be run in parallel in identical hydroponic cultivation chambers (each with 3 optimum performing species of plants, with one plant from each variety in a 15x15 cm tray, each with its own MFC stack and MEC) and hosted by each member of the consortium, with expert input from members of each team (CSIC, SOTON, UWE, SONY). MFCs will be made and deployed by SOTON; hydroponics setup is overseen by UWE. Work is done locally with different foci and results shared via a *virtual laboratory platform* that allows collaboration and sharing of results. Each cultivation chamber is fed with standardised amounts of carbon (atmospheric CO_2) and N ("mock" wastewater formulated in a recipe with an average composition of different wastewater). Only SOTON will use minimum amounts of collected urine in the MFC stacks (*see Use of Urine in MFCs* p23), whose new labs at the Future Towns Innovation Hub are containment level 2 because of the work carried out in the group in general. Modified organisms are mainly used by CSIC and are all BSL1. The CSIC ethics committee mandates the elimination of genetically modified microorganisms after use it to prevent their release into the environment. The Spanish legislation that regulates this are the Notifications A/ES/05/I-11 and A/ES/11/I-02 (resolutions of March 6, 2006, and July 1, 2011). UWE will be operating a station at BSL1, but also has the capability to operate at BSL2 and with GMOs if desirable for the project. Work at UWE will be covered by the UK Advisory Group on Dangerous Pathogens (UKAGDP) Regulations 2017. At UWE labs BSL1 and BSL2 organisms can be used under UKAGDP under the UWE Health and Safety Standard 21 'Work with Biological Agents'.

For GMOs UWE is under the UK Health and Safety Executive GMO (contained use) Regulations using UWE Health and Safety Standard 22 'Work with GMOs' which prevents their release into the environment.

Artificial Intelligence

The development of the AI is therefore (according to our reasoning above) carried out according to the EU's "Ethics Guidelines for Trustworthy AI" 2019 in that it has three components, which will be met throughout the system's entire life cycle: (1) it is lawful, complying with all applicable laws and regulations (2) it is ethical, where ethical principles and values are adhered to and (3) it will be robust, both from a technical and social perspective. The Mi-Hy consortium will ensure that the development, deployment and use of AI systems meets the seven key requirements for Trustworthy AI: (1) human agency and oversight, (2) technical robustness and safety, (3) privacy and data governance, (4) transparency, (5) diversity, non-discrimination and fairness, (6) environmental and societal well-being and (7) accountability. The Mi-Fi consortium will consider technical and non-technical methods to ensure the implementation of those requirements.