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Graphene, MXene and ionic liquid-based sustainable supercapacitor

GREEN CAP

GREENCAP - Deliverable report

D4.2 – Industrial chain manufacturing

Funded by the European Union

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V2.0			

Project summary

GREENCAP focuses on developing high-performance, sustainable cylindrical supercapacitors that exhibit battery-like energy density, high power densities, and long cycle life, by using graphene and MXenes as electrode materials and ionic liquids for high-voltage electrolytes. The use of 2D layered materials and ionic liquids will enhance the specific surface area, ion accessibility, and charge storage while ensuring stability and safety across a wide temperature range.

The consortium consists of academic and industrial partners from six EU countries, the UK and Ukraine. GREENCAP addresses the energy storage sector, while also meeting the EU's climate-neutrality goals and the Action Plan on Critical Raw Materials. GREENCAP will validate this supercapacitor technology at an industrial scale (TRL 6) and develop a management system to optimize its integration into high-end applications and the circular economy.

Publishable summary

The deliverable 4.2 reports the initial efforts of the Greencap industrial partners, nominally Bedimensional SpA, Solvionic, Skeleton Technologies, Skeleton Materials GmBH and Carbon Ukraine, in establishing a manufacturing chain line and supply chain for sustaining the potential industrial and commercial outcome of the project research.

The supply chain of all the supercapacitor components has been considered and its establishment will be completed by the end of the project. Currently, the aspects regarding the industrially produced materials within the consortium have been assessed, leveraging on the knowledge of each industrial partner for the material production and, specially, on the expertise of Skeleton Technologies for the supercapacitor industrial production and commercialization.

Contents

List of Figures

Abbreviations & Definitions

Abbreviation	Explanation
2D	2 dimensional
AEO-F	Authorised Economic Operator
SOLV	Business to businessSolvionic
BED	BeEDdimensional
CapEx	Capital Expenditure
CDC	Carbide derived carbon
CG	Curved graphene
CMC	Carboxymethyl cellulose
CRM	Critical raw material
CU	Carbon Ukraine
EM	Electrode material
ESR	Equivalent series resistance
FLG	Few-layer graphene
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
IATA	International Air Transport Association's
IL	Ionic liquid
NMP	N-Methyl-2-pyrrolidone
PFAs	Poly-fluoroalkalyl substances
REACH	Registration, Evaluation, Authorisation and restriction of CHemicals
SC	Supercapacitor
SKL	Skeleton Technologies
SM	Skeleton Materials GmBH
TCD	Trinity College Dublin
TUD	Technische Universitat Dresden

1 Introduction

This document describes the efforts of the industrial partners of the consortium to define and establish an industrial manufacturing and supply chain capable of sustaining the production of supercapacitors materials and of the supercapacitor cells themselves. Specifically, all the main components, such as the electrode materials (EMs) and ionic liquid (IL) -based electrolytes, are produced and provided by the consortium. Moreover, all the industrial processes for the production and assembly of the final prototype are present within the facilities of the industrial partners, thus the final product would not require external assistance from third parties.
The ultimate goal of the deliverable is to pursue the establishment of fundamentals for the eventual commercialization of supercapacitors (SCs) based on ILs and on novel 2 dimensional (2D) materials, such as graphene and MXenes.
The work described herein was carried out in the context of WP4, which also aims to the upscaling and quality standardization of EMs and IL-based electrolytes. The final aim of WP4 is the development and validation of an industrial relevant prototype (cylindrical cell) and of its control management system.

The WP4 is divided in four main tasks:

- Task 4.1: Upscaling and standardization
  Upscaling of electrolyte, electrode materials and slurries defining the quality control protocols and standardization. It will be followed by an update (D4.5) in the month 36 of the project.

- Task 4.2: Industrial chain manufacturing chain
  This document. It will be followed by an update (D4.6) in the month 36 of the project.

- Task 4.3: Cylindrical prototype cell
  Initial production and testing of a cylindrical cell prototype. It will be followed by an update (D4.7) in the month 36 of the project.

- Task 4.4: Preliminary supercapacitor management system
  Initial design and validation of the supercapacitor management system (SMS)

Key achievements:

- The cost of the few-layer graphene production is reduced below 1000 €/kg by the up-scaling to 3 t/year by BeDimensional.
- The supply chain efficiency and material management have been improved by the definition of a standardization protocol according to the ISO TS 21356-1 and by assessing the REACH registration for few-layer graphene and the $Pyr_{13}BF_4$ ionic liquid.
- The route to the up-scaled production of Pyr11BF4 and Pyr13BF4 has been identified in the flow reactor pilot line and in the new industrial production plant planned by SOLV. Such upscale production will reduce the costs and the prices of the electrolytes under 100 €/kg.
- Establishment of the 2D materials and ionic liquids supply chain for supercapacitor application

2 Results and discussion

2.1 Solvionic electrolytes

Solvionic (SOLV) has an established industrial chain for manufacturing, processing and distributing ILs. The most promising electrolytes within the Greencap project are Pyr11BF4 and Pyr13BF4 in acetonitrile. The production and formulation of these compounds takes place at SOLV in Toulouse (France).

Table 1: Electrolyte products designation, ECHA, and CAS references.

IUPAC name	Abbreviation	EC	CAS
dimethylpyrrolidinium tetrafluoroborate	Pyr11BF4	834-341-9	69444-51-5
N-propyl-N-methylpyrrolidinium tetrafluoroborate	Pyr13BF4	801-426-7	327022-59-3
Acetonitrile	ACN	200-835-2	75-05-8

2.1.1 Processes

As detailed in D4.1, SOLV possesses the technology necessary to produce ILs. With SOLV current pilot line, 1.5 t/month of IL can be produced. The installation of a larger production line at SOLV site in Toulouse is planned as to increase capacity as part of SOLV industrialisation roadmap, see below.

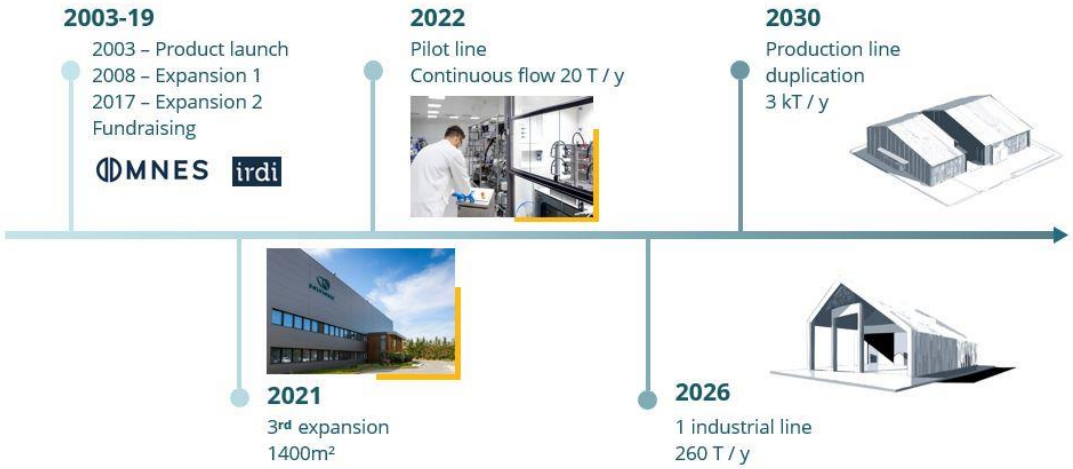

Figure 1: SOLV industrialization roadmap.

2.1.2 Raw materials

SOLV works with well-known suppliers of chemicals from Europe and Asia to import the raw materials necessary to produce SOLV product portfolio. The names and details of these suppliers are withheld for confidentiality reasons. In the case of the large-scale production of an electrolyte such as the ones explored in Greencap, a revaluation of these supply chains could be necessary. However, SOLV has developed strong commercial relationships with leading chemicals suppliers and has experienced staff dedicated to acquiring and securing supply chains as part of the industrial roadmap.

2.1.3 Cost evaluation of electrolytes

The price of these electrolytes per kilogram were calculated for two electrolytes: Pyr13BF4 in acetonitrile and Pyr11BF4 in acetonitrile. This price reflects the cost of production and of distribution of these electrolytes at the envisaged scale of 10^5 kg/year (10 t). The price of Pyr13BF4 is lower than that of Pyr11BF4 electrolytes.

Table 2: Pyr11BF4 and Pyr13BF4 based electrolytes price based on production scale.

Quantity (ton)	Price of Pyr13BF4 in ACN (€/kg)	Price of Pyr11BF4 in ACN (€/kg)
10	150	314
20	122	152
50	110	142
100	85	98

2.1.4 Reach certification

The Registration, Evaluation, Authorisation and restriction of CHemicals (REACH) is a European regulation related to chemicals which aims to:

- Protect human health and the environment
- Allow free movement of materials within the EU
- Increase the competitiveness of the EU chemical market
- Reduce animal testing by encouraging alternative methods of assessing chemicals

Pyr11BF4 is fully REACH registered (estimated band 1 – 10 tonnes) as of the November 2023 and has the following Globally Harmonized System of Classification and Labelling of Chemicals (*GHS*): H301 (Toxic if swallowed), H319 (Causes serious eye irritation), H412 (Harmful to aquatic life with long lasting effects).

Acetonitrile is fully REACH registered (estimated band 10 000– 100 000 tonnes) and has the following GHS : H302 (Harmful if swallowed), H312 (Harmful in contact with skin), H332 (Harmful if inhaled), H319 (Causes serious eye irritation), H225 (Highly flammable liquid and vapour).

Pyr13BF4 is not REACH registered. In the case of upscaled production and distribution of this electrolyte, **REACH certification should be obtained**. SOLV has previously applied and gained REACH certification for the IL Pyr13FSI (CAS 852620-97-4) in 2021. Building on SOLV experience and the existing information for the very similar Pyr11BF4, REACH certification for Pyr13BF4 could be initiated and processed by SOLV.

2.1.5 Distribution

Distribution methods of electrolytes depend on the volume and timeframe although this is generally undertaken *via* **land freight or air**. The production of larger quantities of electrolytes could potentially require other means of transportation.

2.1.6 Containers

SOLV uses different containers for shipping flammable liquids. These liquids are shipped in pure aluminium containers, **approved for the transport of dangerous goods (UN Transport Regulation)** and packaged into **UN approved cartons**. The containers are 100% recyclable and present embossed codes for comprehensive traceability.

2.1.7 Certification

SOLV logistics team has the International Air Transport Association's (IATA) dangerous good training and certification. This allows SOLV to prepare and **send dangerous goods by air**.

As of 2024, SOLV is a recognised **Authorised Economic Operator (AEO-F)**. Having OEA status has different benefits:

- Facilitated customs controls
- Reduced costs for customs procedures
- Accelerated procedures for goods entering or leaving the customs territory
- Advanced notification of security checks
- Priority in the event of a customs inspection

The AEO status is recognised by the European Union, China, Japan, Norway, Switzerland and the United States, making shipping easier and more efficient.

2.1.8 Retail and sales

As the leading manufacturer of ILs, SOLV has many international distribution partners around the world, including Nanofaber in Italy and Chem-Supply PTY LTD in Australia, in addition to partners in China, USA, Korea and Japan among others.

2.2 Skeleton Curved Graphene

As described in D4.1, the raw materials used to produce curved graphene (CG) are silicon carbine, sodium hydroxide, chlorine, argon and hydrogen gasses.

2.2.1 Industrial Manufacturing

Continuous refinement of the manufacturing chain, supported by cost modelling and process simulations enables the identification of bottlenecks and high-cost areas, guiding strategic investments in automation, material substitution, or process redesign. Employee salaries represent the largest portion of operational expenses, accounting for approximately 70% of the total annual costs. This is followed by material procurement, which makes up around 8%, and electricity consumption, contributing roughly 1%. Facility rent constitutes about 10% of the yearly expenditure. The remaining budget is allocated to other operational needs and a gradually increasing capital expenditure (CapEx) plan, which is set to scale over the next three years to support process optimization and technological upgrades.

2.3 BeDimensional Few-layer graphene

Bedimensional (BED) has an established industrial chain for the production and distribution of 2D materials. Within the Greencap project BED few-layer graphene (FLG) has been adopted as the conductive additive for the SC electrodes. The production of FLG is located at BED production plant in Genoa (Italy).

2.3.1 Processes and raw materials

As described in D4.1, FLG is produced by BED through a proprietary method based on the wet-jet-milling process. BED currently has two fully operative plants for a total production capacity of 3.5 tonnes per year. Currently, the raw materials used for the production of FLG consist in natural graphite and N-methyl-2-pyrrolidone (NMP) as the liquid medium. The NMP is almost completely (98 %) recovered during the drying process and recycled within the production system, minimizing its ecological footprint. During the Greencap project, BED demonstrated that NMP can be substituted by water with a low amount of surfactant, which is currently under optimization for satisfying the BED quality requirements. The substitution of NMP with water further enhance the sustainability of the FLG production process. Moreover, being natural graphite recognized as critical raw materials (CRM), BED is currently developing the transition to synthetic graphite. Regarding the supply chain, BED prioritize European graphite sources and chemical suppliers but can count also on Asian providers. The names and details of the graphite and NMP suppliers are withheld for confidentiality reasons.

2.3.2 Cost evaluation of FLG

The cost of FLG is principally determined by the cost of the personnel which weight about the 40-50% of the total cost. Its exact production cost is covered by confidential but is less than 1000€/kg for 3 t/year production plant. Further upscaling of the production is expected to lower the cost significantly by 2030.

2.3.3 Distribution and containers

FLG is distributed by land or air transport, depending on the distance. Currently, BED is evaluating other transport solutions for addressing large volume shipments. The containers employed from BED for the shipments of its products are watertight sealed, in order to avoid water contamination, and they are made by aluminium, in case of pastes, or by recyclable plastics in case of powders.

2.3.4 Sales and distributor

BED sales strategy consists in establishing a stable and trusting relationship with the client through a continuous support for the integration of 2D materials within the client products, resulting in a direct sales outcome.

Beside direct sales, BED exploits both Italian and European dealers and business-to-business online platforms.

2.3.5 Certifications

All the BED products, such as the G-LEAF, which is the proprietary name of the FLG produced and sold by BED, are provided with safety data sheet (SDS) according to the Commission Regulation (EU) 2020/878. An example of the SDS provided is attached to this document (Appendix B).

Moreover, BED, as also stated on D4.1, is currently pursuing the procedures for obtaining the REACH certification for the 2D materials produced by WJM for the production range (1-10) t.

2.3.6 Carbon Ukraine MXenes

The production of MXenes at Carbon Ukraine (CU) is based entirely on the use of European raw materials and locally sourced chemicals and reagents, primarily from Ukraine. The key precursor for MXene synthesis—MAX phase powders—is produced in-house at our facility in Kyiv using local raw materials. For example, the synthesis of Ti_3AlC_2 (the precursor for Ti_3C_2 MXene) relies on titanium sponge, titanium carbide powders, graphite, and carbon black—all of which are widely produced and mined in Ukraine. The country has some of the largest titanium and graphite reserves in Europe, enabling regional production of these strategic raw materials without dependence on non-European supply chains.

CU collaborates with suppliers located in Kyiv, the same city as our production site, ensuring a fast and uninterrupted supply chain. All raw materials are delivered by local couriers or freight services via road transport, typically within one to three days.

The MXene synthesis process also requires various salts (chlorides and fluorides) and hydrochloric acid, all of which are sourced from local Ukrainian manufacturers. Deionized water, required for purification steps, is either produced in-house or procured from nearby suppliers. Additionally, high-purity argon gas is supplied by a specialized industrial gas producer also located in Kyiv.

This fully localized and Europe-based supply chain ensures stable, cost-effective, and scalable production capabilities, with minimal logistics-related risks and transportation costs.

Ukraine, as part of the European region, is known for its extensive, actively developed reserves of titanium ores and high-quality graphite—key inputs for MAX phase and MXene production. This unique advantage allows CU to establish a competitive, secure, and sustainable supply chain to support EU-focused industrial applications.

CU is committed to building a full-cycle proprietary production of MAX phases and MXenes in Europe, using only European raw materials. This approach is aligned with EU strategic autonomy goals and addresses the growing demand for advanced materials in energy storage, including SCs and battery technologies.

2.4 Binder, separator, current collectors

The binder components (carboxyl-methyl cellulose – CMC, acrylic additives and styrene-butadiene rubber), as well as the separator (cellulose) and the current collectors (carbon-coated aluminium foils)

are provided by external suppliers exploiting the experience of Skeleton Technologies (SKL) in the SC field. The Greencap consortium at this stage of the supply chain development, is collecting the information from the experience of SKL in order to contact and establish relationships able to potentially provide a stable supply of the required components. Further update will be provided in D4.6 (M36).

2.5 Skeleton supercapacitor assembly

D4.2 summarizes the preliminary results of task 4.2, which is about industrial manufacturing chain development. More specifically an overview for SKL industrial production for electrode, electrolyte and cylindrical cells is given.

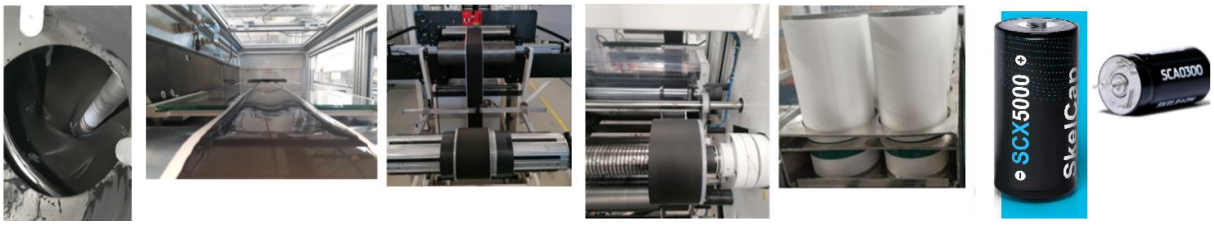

Figure 2: Production process overview

2.5.1 Electrode material:

The electrode material production is described in D4.1.

2.5.2 Electrode manufacturing:

1. Mixing

The CG produced by SM was mixed using a planetary mixer. As the SKL facility does not have a suitable capacity, the mixing was performed by Eirich, a mixing equipment manufacturer, in batches of 50 L. Electrode active material and conductive additive were added to the mixer in their respective amounts. An industrial dispersive binder Na-CMC powder was added and the dry powders mixed. The remaining electrode material was added with water to the kneading point. Acrylic binder is then added to the bowl and the mixture is gradually diluted and sampled until specifications are met.
The resulting slurry is then transferred to a shipping container. Slurry samples are collected from each batch to measure the properties for the purpose of quality control.

2. Coating

Currently, a single layer of slurry is coated on the Al foil, followed by a successive coating of the opposite side, marking the anode and cathode of the capacitor, with the cathode typically coated sightly thicker. In the future, simultaneous double coating would be preferred, as this would decrease the manufacturing time.

3. Calendering

In this process the main coated roll is pressed, and the electrode thickness is adjusted to a certain value. The electrode surfaces become uniform. The calendering machine has two pressing rollers along with an infrared heating system to ensure residual moisture removal. Measurement of the thickness

is also implemented to ensure a consistent product. Based on the thickness scanned by the thickness gauge prior to calendaring, the pressing unit gap will be automatically adjusted.

4. Slitting

Subsequently, the main roll is cut during the slitting process according to the dimensions of a D60 cylindrical cell, i.e. 60 mm diameter and 115 mm width. The cutting width is the critical quality parameter in this process. To ensure the coating width, vision systems are included in the slitting process. During the cutting process all components are continuously monitored.
After this stage, the electrode is ready for cell assembly.

2.5.3 Cell production with assembly and welding

1. Winding

The slitted electrode, along with the separator paper and sealing tape, is loaded into the winding machine. The resulting electrode rolls are automatically transferred onto a conveyor and moved to the electrode roll forming station. Each individual roll is then prepared for cell assembly, followed by the connection between the cell and the roll.

2. Forming

The goal of the forming process is to fold-over the ends of the electrode rolls to create flat surfaces onto which the tabs will be welded. In this process it is important to ensure that the filling path, in the centre of the jelly roll, remains open after forming and that the surface is correctly prepared for the tab welding steps.

3. Welding

The top and bottom tabs are welded onto the jelly rolls by using a laser welding equipment. The welding path and tab are designed ensuring an efficient welding all over the contact surface. This is particularly important to achieve a low ESR in the final product. The lid is welded to the top tab by a stationary laser beam and by rotating the jelly roll a full revolution.

4. Taping

Prior to assembling the jelly roll to a can, it is important to ensure that there is good insulation between top tab and the bottom tab. To achieve this, insulation tape is applied to the top part of the jelly roll. A visual inspection must be conducted on the taping to ensure that there is a continuous application of the insulation tape in the correct position. A gasket is placed on top of the jelly roll which will provide insulation and ensuring a leak tight connection at the top of the cell.

5. Can insertion

The taped roll is inserted into the casing, a standard D-type cell format manually. The can is additionally engraved using laser-writing for identification.

6. Beading

The can is closed by pressing a lid and bottom to it. In the beading process a roller rotates around the can and reduces the diameter in the area of the gasket to centralize the jelly roll assembly inside of the can.

7. Crimping

A roll from the top moves down and bends over the top edges of the can onto the gasket to keep the jelly roll assembly securely inside of the can and compress the gasket to create a leak-tight connection.

8. Welding

Leak-tightness at the bottom of the can is created by laser welding the bottom tab to the can with specific equipment.

9. Drying

The drying step is needed to remove water particles from the electrode before filling. The ovens used are vacuum ovens that heat up the chamber and creates a vacuum to "pull" the water out of the cell. The drying step is a time-consuming process, but essential for the lifetime of the final product. To prevent the dried cells from contacting "wet" air, the ovens are integrated into a dry room where the cells will remain until they are filled with electrolyte and permanently sealed.

2.5.4 Filling and testing

1. Filling

In the filling process electrolyte is injected into the cell. This is achieved by first creating a high vacuum inside the cell that will support the cell in receiving the electrolyte and pushing with a piston-cylinder. The amount of electrolyte injected into the cell is validated by weighing the cell before and after filling. A rubber plug is fitted to the cell to temporarily seal the cell and to also create a barrier between the electrolyte and the final closing step.

2. Closing

To prevent any electrolyte residue on the cell, a surface laser cleaning is used to clean the welding surface prior to the pin insertion and welding. A closing pin is fitted onto the top terminal and welded to the lid with laser welding equipment.

3. EOL testing

Self-discharge time, ESR, capacitance are all parameters measured for the EOL testing, to ensure a high-quality reliable product.

2.6 Packaging, logistics and distribution of SC

The Greencap consortium is collecting the information from SKL to potentially establish a distribution chain capable of sustaining an eventual commercial outcome.

2.7 Contribution to project (linked) Objectives

- The cost of the few-layer graphene production is reduced below 1000 €/kg by the up-scaling to 3 t/year by BeDimensional.
- The supply chain efficiency and material management have been improved by the definition of a standardization protocol according to the ISO TS 21356-1 and by assessing the REACH registration for few-layer graphene and the $Pyr_{13}BF_4$ ionic liquid.
- The route to the up-scaled production of Pyr11BF4 and Pyr13BF4 has been identified in the flow reactor pilot line and in the new industrial production plant planned by SOLV. Such upscale production will reduce the costs and the prices of the electrolytes under 100 €/kg.

2.8 Contribution to major project exploitable result

- The development of 2D materials and ionic liquids supply chain for supercapacitor application.

3 Conclusion and Recommendation

The consortium started to establish the supplying chain line for the supercapacitor cylindrical cell production. Specifically, Solvionic started to produce in small batches the electrolytes selected within the project and assessed the capability of eventually produce, previous production parameters optimization, the Greencap electrolytes on its pilot plant. BeDimensional reached the production goal and is evaluating the transition to synthetic graphite and water, used as raw materials instead natural graphite and NMP. Carbon Ukraine established a MXene supply chain entirely based on European suppliers to produce low-fluorine etching system. SKL shared its experience as a supercapacitor producer.

The supplying and manufacturing chain development will continue through the last 6th months of the project aiming to realize an established consortium to produce supercapacitor.

4 Risks and interconnections

4.1 Risks/problems encountered

N/A

4.2 Interconnections with other deliverables

The deliverable 4.2 describes the consortium efforts for establishing and optimizing the manufacturing and supply chain lines for supporting the production of supercapacitors based on novel 2D materials and ILs. Thus, it is deeply connected with the other deliverables of WP4, specifically to the deliverables 4.1, 4.3 and 4.4, as well as their updates (D4.5, D4.7 and D4.8). Moreover, the deliverable 4.2 will be updated in month 36 with the publication of D4.6.

5 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Project partners:

#	Partner short name	Partner Full Name
1	BED	BEDIMENSIONAL SPA
2	SOLV	SOLVIONIC
3	FSU	FRIEDRICH-SCHILLER-UNIVERSITAT JENA
4	SKL	SKELETON TECHNOLOGIES OU
5	TCD	THE PROVOST, FELLOWS, FOUNDATION SCHOLARS & THE OTHER MEMBERS OF BOARD, OF THE COLLEGE OF THE HOLY & UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN
6	TUD	TECHNISCHE UNIVERSITAET DRESDEN
7	UNISTRA	UNIVERSITE DE STRASBOURG
8	SM	SKELETON MATERIALS GMBH
9	UNR	UNIRESEARCH BV
10	CNR	CONSIGLIO NAZIONALE DELLE RICERCHE
11	UCAM	THE CHANCELLOR MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE
12	CU	Y CARBON LLC

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6 Appendix A - Quality Assurance Review Form

The following questions should be answered by all reviewers (WP Leader, reviewer, Project Coordinator) as part of the Quality Assurance procedure. Questions answered with NO should be motivated. The deliverable author will update the draft based on the comments. When all reviewers have answered all questions with YES, only then can the Deliverable be submitted to the EC.

NOTE: This Quality Assurance form will be removed from Deliverables with dissemination level "Public" before publication.

Question	WP Leader	Reviewer	Project Coordinator
	Paul Ionescu (SKL)	Alix Ladam (SOLV)	Francesco Bonaccorso (BED)
1. *Do you accept this Deliverable as it is?*	Yes	Yes	Yes
2. *Is the Deliverable complete?* - *All required chapters?* - *Use of relevant templates?*	Yes	Yes	Yes
3. *Does the Deliverable correspond to the DoA?* - *All relevant actions preformed and reported?*	Yes	Yes	Yes
4. *Is the Deliverable in line with the GREENCAP objectives?* - *WP objectives* - *Task Objectives*	Yes	Yes	Yes
5. *Is the technical quality sufficient?* - *Inputs and assumptions correct/clear?* - *Data, calculations, and motivations correct/clear?* - *Outputs and conclusions correct/clear?*	Yes	Yes	Yes
6. *Is created and potential IP identified and are protection measures in place?*	Yes	Yes	Yes
7. *Is the Risk Procedure followed and reported?*	Yes	Yes	Yes
8. *Is the reporting quality sufficient?* - *Clear language* - *Clear argumentation* - *Consistency* - *Structure*	Yes	Yes	Yes

7 Appendix B – Safety Data Sheet

BEDIMENSIONAL

SAFETY DATA SHEET

according to Commission Regulation (EU) 2020/878 as amended

G-LEAF 09900

Creation date	21st April 2022		
Revision date	05th June 2025	Version	3.0

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier — G-LEAF 09900

Substance / mixture	substance
Chemical name	Graphene
CAS number	1034343-98-0
EC (EINECS) number	801-282-5

1.2. Relevant identified uses of the substance or mixture and uses advised against

Substance's intended use

The product is used in scientific research and development as a chemical additive.
SU24: Scientific research and development.

Main identified uses

PC-PNT-OTH Other paints and coating materials

Substance uses advised against

The product should not be used in ways other than those referred in Section 1.

1.3. Details of the supplier of the safety data sheet

Manufacturer

Name or trade name	BeDimensional S.p.A.
Address	Via Lungotorrente Secca, n.30/r 16163 Italy
Phone	010 2364170
E-mail	*info@bedimensional.it*

Competent person responsible for the safety data sheet

Name	Elisa Mantero
E-mail	e.mantero@bedimensional.it

1.4. Emergency telephone number

Hosp. Niguarda Ca 'Granda - Milan - +39 02-66101029

CAV National Toxicological Information Center - Pavia - +39 0382-24444

Papa Giovanni XXII Hospital - Bergamo - + 39 800 883300

Az. Osp. "Careggi" U.O. Medical Toxicology - Florence - +39 055-7947819

CAV Policlinico "A. Gemelli" - Rome - +39 06-3054343

CAV Policlinico "Umberto I" - Rome - +39 06-49978000

Az. Osp. "A. Cardarelli" - Naples - +39 081-5453333

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

Classification of the substance in accordance with Regulation (EC) No 1272/2008

The substance is classified as dangerous.

Aquatic Chronic 3, H412

Most serious adverse effects on human health and the environment

Harmful to aquatic life with long lasting effects.

2.2. Label elements

Dangerous substance

Graphene
(EC: 801-282-5; CAS: 1034343-98-0)

Hazard statements

H412	Harmful to aquatic life with long lasting effects.

Precautionary statements

P273	Avoid release to the environment.
P501	Dispose of contents/container to by handing over to the person authorized to dispose of waste or by returning to the supplier.

2.3. Other hazards

The substance does not have endocrine disrupting properties in accordance with the criteria set out in Commission Delegated Regulation (EU) 2017/2100 or Commission Regulation (EU) 2018/605. Substance does not meet the

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criteria for PBT or vPvB in accordance with Annex XIII of Regulation (EC) No. 1907/2006 (REACH) as amended. Does not contain any PMT or vPvM components. Dust may form explosive mixture with air.

SECTION 3: Composition/information on ingredients

3.1. Substances

Chemical characterization

The substance specified below.

Identification numbers	Substance name	Content in % weight	Classification according to Regulation (EC) No 1272/2008	Note
	substance main component			
CAS: 1034343-98-0 EC: 801-282-5	Graphene	100	Aquatic Chronic 3, H412	Nanoform

Full text of all classifications and hazard statements is given in the section 16.

SECTION 4: First aid measures

4.1. Description of first aid measures

Take care of your own safety. If any health problems are manifested or if in doubt, inform a doctor and show him information from this safety data sheet.

If inhaled

Terminate the exposure immediately; move the affected person to fresh air. Protect the person against growing cold. Provide medical treatment if irritation, dyspnoea or other symptoms persist.

If on skin

Remove contaminated clothes. Wash the affected area with plenty of water, lukewarm if possible. Soap, soap solution or shampoo should be used if there is no skin injury. Provide medical treatment if skin irritation persists.

If in eyes

Rinse eyes immediately with a flow of running water, open the eyelids (also using force if needed); remove contact lenses immediately if worn by the affected person. Rinsing should continue at least for 10 minutes.

If swallowed

Rinse out the mouth with clean water. In the event of issues, find medical help.

4.2. Most important symptoms and effects, both acute and delayed

If inhaled

With current knowledge, the substance gives no evidence of acute or delayed effects

If on skin

With current knowledge, the substance gives no evidence of acute or delayed effects

If in eyes

With current knowledge, the substance gives no evidence of acute or delayed effects

If swallowed

With current knowledge, the substance gives no evidence of acute or delayed effects

4.3. Indication of any immediate medical attention and special treatment needed

Symptomatic treatment.

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media

Alcohol-resistant foam.

Unsuitable extinguishing media

Water - full jet.

5.2. Special hazards arising from the substance or mixture

In the event of fire, carbon monoxide, carbon dioxide and other toxic gases may arise. Inhalation of hazardous degradation (pyrolysis) products may cause serious health damage.

5.3. Advice for firefighters

Self-Contained Breathing Apparatus (SCBA) with a chemical protection suit only where personal (close) contact is likely. Use a self-contained breathing apparatus and full-body protective clothing. Do not allow run-off of contaminated fire extinguishing material to enter drains or surface and ground water.

BEDIMENSIONAL

SAFETY DATA SHEET

according to Commission Regulation (EU) 2020/878 as amended

G-LEAF 09900

Creation date	21st April 2022		
Revision date	05th June 2025	Version	3.0

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Use personal protective equipment for work. Follow the instructions in the Sections 7 and 8.

6.2. Environmental precautions

Prevent contamination of the soil and entering surface or ground water.

6.3. Methods and material for containment and cleaning up

Place the product mechanically in an appropriate manner. Dispose of the collected material according to the instructions in the section 13.

6.4. Reference to other sections

See the Section 7, 8 and 13.

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Use personal protective equipment as per Section 8. Observe valid legal regulations on safety and health protection. Avoid release to the environment.

7.2. Conditions for safe storage, including any incompatibilities

Store in tightly closed containers in cold, dry and well ventilated areas designated for this purpose.

7.3. Specific end use(s)

not available

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Occupational exposure limits are set for the substance

Substance name (component)	Type	Value	Source
Breathable dusts	TLV-TWA	3 mg/m³	ACGIH

8.2. Exposure controls

Do not eat, drink and smoke during work. Wash your hands thoroughly with water and soap after work and before breaks for a meal and rest.

Eye/face protection

It is not needed.

Skin protection

Hand protection: Protective gloves resistant to the product. When choosing appropriate thickness, material and permeability of the gloves, observe recommendations of their particular manufacturer. Contaminated skin should be washed thoroughly.

Glove material	Thickness	Breakthrough time	Class
Neoprene (CR)	0.7 mm	>480 min	6

Respiratory protection

It is not needed.

Thermal hazard

Not available.

Environmental exposure controls

Observe usual measures for protection of the environment, see Section 6.2.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state	Solid
Colour	Black
Odour	data not available
Melting point/freezing point	> 3000° C
Boiling point or initial boiling point and boiling range	data not available
Flammability	data not available

BEDIMENSIONAL

SAFETY DATA SHEET

according to Commission Regulation (EU) 2020/878 as amended

G-LEAF 09900

Creation date	21st April 2022		
Revision date	05th June 2025	Version	3.0

Lower and upper explosion limit	data not available
Flash point	data not available
Auto-ignition temperature	data not available
Decomposition temperature	data not available
pH	data not available
Kinematic viscosity	data not available
Solubility in water	data not available
Partition coefficient n-octanol/water (log value)	data not available
Vapour pressure	data not available
Density and/or relative density	data not available
Relative vapour density	data not available
Particle characteristics	one dimensional nanoform with thickness between 1 and 100nm (nanoform)
Forma	Solid substance - nanoform

Graphene (CAS: 1034343-98-0)

9.2. Other information

not available

SECTION 10: Stability and reactivity

10.1. Reactivity

The substance is non-flammable.

10.2. Chemical stability

The product is stable under normal conditions.

10.3. Possibility of hazardous reactions

To the best of our current knowledge, no adverse reactions are known.

10.4. Conditions to avoid

The product is stable and no degradation occurs under normal use. Protect against flames, sparks, overheating and against frost.

10.5. Incompatible materials

Protect against strong acids, bases and oxidizing agents.

10.6. Hazardous decomposition products

Not developed under normal uses. Dangerous outcomes such as carbon monoxide and carbon dioxide are formed at high temperature and in fire.

SECTION 11: Toxicological information

11.1. Information on hazard classes as defined in Regulation (EC) No 1272/2008

No toxicological data is available for the substance.

Acute toxicity

No known effects.

Skin corrosion/irritation

No known effects.

Serious eye damage/irritation

No known effects.

Respiratory or skin sensitization

No known effects.

Germ cell mutagenicity

No known effects.

Carcinogenicity
No known effects.

Reproductive toxicity
No known effects.

Toxicity for specific target organ - single exposure
No known effects.

Toxicity for specific target organ - repeated exposure
No known effects.

Aspiration hazard
No known effects.

11.2. Information on other hazards

Endocrine disrupting properties
Based on available data the classification criteria are not met. Does not contain any components that may cause endocrine disruption for humans.

Other information
not available

SECTION 12: Ecological information

12.1. Toxicity
Harmful to aquatic life with long lasting effects.

12.2. Persistence and degradability
No data available for the substance.

12.3. Bioaccumulative potential
No data available for the substance.

12.4. Mobility in soil
Based on available data the classification criteria are not met. Does not contain any PMT or vPvM components.

12.5. Results of PBT and vPvB assessment
Based on available data the classification criteria are not met. Does not contain any PBT or vPvB components.

12.6. Endocrine disrupting properties
Based on available data the classification criteria are not met. Does not contain any components that may cause endocrine disruption in the environment.

12.7. Other adverse effects
Not available.

SECTION 13: Disposal considerations

13.1. Waste treatment methods
Hazard of environmental contamination; dispose of the waste in accordance with the local and/or national regulations. Any unused product and contaminated packaging should be put in labelled containers for waste collection and submitted for disposal to a person authorized for waste removal (a specialized company) that is entitled for such activity. Do not empty unused product in drainage systems. The product must not be disposed of with municipal waste. Empty containers may be used at waste incinerators to produce energy or deposited in a dump with appropriate classification. Perfectly cleaned containers can be submitted for recycling.

Waste management legislation
Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste, as amended. Decision 2000/532/EC establishing a list of wastes, as amended.

SECTION 14: Transport information

14.1. UN number or ID number

BEDIMENSIONAL

SAFETY DATA SHEET

according to Commission Regulation (EU) 2020/878 as amended

G-LEAF 09900

Creation date	21st April 2022		
Revision date	05th June 2025	Version	3.0

not subject to transport regulations

14.2. UN proper shipping name
not relevant

14.3. Transport hazard class(es)
not relevant

14.4. Packing group
not relevant

14.5. Environmental hazards
not relevant

14.6. Special precautions for user
Reference in the Sections 4 to 8.

14.7. Maritime transport in bulk according to IMO instruments
not relevant

SECTION 15: Regulatory information

15.1. Safety, health and environmental regulations/legislation specific for the substance or mixture
Legislative decree no. 81 of 09 April 2008 on health and safety protection of employees in the workplace. Legislative Decree No. 200/2011 - Sanctions for the violation of the provisions on the export and import of dangerous chemical substances – Official Gazette no. 283 of 05 December 2011. Regulation (EC) No. 1907/2006 of the European Parliament and of the Council of 18th December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), establishing the European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No. 793/93 and Commission Regulation (EC) No. 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, as amended. REGULATION (EC) No. 1272/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL as amended. Commission Regulation (EU) 2020/878 of 18 June 2020 amending Annex II to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH).

15.2. Chemical safety assessment
not available

SECTION 16: Other information

A list of standard risk phrases used in the safety data sheet

H412	Harmful to aquatic life with long lasting effects.

Guidelines for safe handling used in the safety data sheet

P273	Avoid release to the environment.
P501	Dispose of contents/container to by handing over to the person authorized to dispose of waste or by returning to the supplier.

Other important information about human health protection
The product must not be - unless specifically approved by the manufacturer/importer - used for purposes other than as per the Section 1. The user is responsible for adherence to all related health protection regulations.

Key to abbreviations and acronyms used in the safety data sheet

ADR	Agreement concerning the international carriage of dangerous goods by road
Aquatic Chronic	Hazardous to the aquatic environment (chronic)
BCF	Bioconcentration Factor
CAS	Chemical Abstracts Service
CLP	Regulation (EC) No 1272/2008 on classification, labelling and packaging of substance and mixtures
EC	Identification code for each substance listed in EINECS
EINECS	European Inventory of Existing Commercial Chemical Substances
EmS	Emergency plan
EU	European Union
EuPCS	European Product Categorization System
IATA	International Air Transport Association
IBC	International Code For The Construction And Equipment of Ships Carrying Dangerous Chemicals
ICAO	International Civil Aviation Organization

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SAFETY DATA SHEET

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Creation date	21st April 2022		
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IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
INCI	International Nomenclature of Cosmetic Ingredients
ISO	International Organization for Standardization
IUPAC	International Union of Pure and Applied Chemistry
log Kow	Octanol-water partition coefficient
OEL	Occupational Exposure Limits
PBT	Persistent, bioaccumulative and toxic
PMT	Persistent, mobile and toxic
ppm	Parts per million
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RID	Agreement on the transport of dangerous goods by rail
UN number	Four-figure identification number of the substance or article taken from the UN Model Regulations
UVCB	Substances of unknown or variable composition, complex reaction products or biological materials
VOC	Volatile organic compounds
vPvB	Very persistent and very bioaccumulative
vPvM	Very persistent and very mobile

Training guidelines

Inform the personnel about the recommended ways of use, mandatory protective equipment, first aid and prohibited ways of handling the product.

Recommended restrictions of use

not available

Information about data sources used to compile the Safety Data Sheet

REGULATION (EC) No. 1907/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (REACH) as amended. REGULATION (EC) No. 1272/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL as amended. Data from the manufacturer of the substance / mixture, if available - information from registration dossiers.

More information

Classification procedure - calculation method.

Statement

The safety data sheet provides information aimed at ensuring safety and health protection at work and environmental protection. The provided information corresponds to the current status of knowledge and experience and complies with valid legal regulations. The information should not be understood as guaranteeing the suitability and usability of the product for a particular application.

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