HARVEST

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Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
CEN	European Committee for Standardization
ISO	International Organization for Standardization

Contents

EXECUTIVE SUMMARY

This deliverable is the final report on standardization activities in the HARVEST project and is complimentary to the initial standardization report (D8.4- Review of relevant standards applicable to the project) submitted in M12 . Within this report, Steinbeis R-Tech, with the cooperation of all the HARVEST consortium partners, evaluated the application of standards which were identified in the first report for production and test methods applicable to HARVEST products.To achieve this goal, first a semantic similarity analysis was carried out to evaluate the similarity of the recognized standards and estimate their relativeness to HARVEST project. Further, a gap analysis was performed using a survey in order to recognize the gaps between the project activities and existence of the relevant standards. The results from the survey showed new standards which were not identified in the earlier stage of standardization. In addition, a step by step strategy has been extracted from the literature to utilize these results in a workflow in order to bridge the gaps.

1 INTRODUCTION

Standardization is a powerful tool to achieve better interoperability. However, it needs to overcome a lack of interest and modest participation from stakeholders. Also, promising research results are not always used as the basis for new standards. In the previous standardization report for HARVEST, a list of standards was introduced which could be applicable to the production and test methods. These standards, including general and technical standards, cover the guidelines for manufacturing and testing of materials/products related to the HARVEST such as epoxy resins, fibers and composites.

The current report aims to identify the applicable standards which were used in practice within the project activities but not acknowledged at the first stage. These standards were mentioned by the partners through the gap analysis. The term “Gap Analysis” in general refers to the evaluation of the current performance and comparing it with desired, expected performance. In standardization, such analyses are intended to indicate possible next areas to be considered towards the development or repositioning of standards and ongoing initiatives.

In the case of HARVEST project, a gap analysis was carried out to screen the production and/or test methods for which the existing standards lack guidelines. In addition, as mentioned, the results led us to discover standards that were used in HARVEST processes, as innovative technologies, in practice but were not identified previousely as a relevant standard. For this purpose, a survey tailored to the HARVEST activities was designed and distributed among the partners. The findings of this survey along with further analysis of relevant standards, such as semantic similarity analysis, form the structure of this report. Therefore the key objectives of this deliverable are:

- ✓ To evaluate the applicability of relevant standards and assess the similarities and overlaps between them
- ✓ To identify other standards that were used in practice
- ✓ To recognize the gaps between the technical work and existing standards
- ✓ To recommend strategic approaches for bridging the standardization gap

The outcomes of the standardization activities can be used to develop further strategies in order to follow the proposed methodology for bridging the gaps and bringing the HARVEST final products to the market possibly through a next collaborative project.

2 SEMANTIC SIMILARITY ANALYSIS OF THE STANDARDS

Document semantic similarity analysis (calculation of similarity in meaning between the texts) was performed using the HARVEST project description in comparison to the abstract text sourced from publicly available standards using the following steps:

In step 1, a summary of HARVEST objectives and methodology was extracted from the project documents. This is followed by collecting the information and abstracts from 28 relevant standards.

The second step involves the calculation of a similarity score is obtained between the values of 0 and 1, where the similarity score is mathematically defined as:

$$S(i,j) = \frac{no.of\ words\ occuring\ in\ w(i)\ and\ w(j)}{Max\ (no.of\ words\ in\ w(i), no.of\ words\ in\ w(j)}$$

The similarity score calculated by quantifying the overlap of semantic similarity of the textual data obtained from abstracts from the selected standards in one hand and the HARVEST project description, on the other.

Step 3 involves extracting the structure and cluster of related items. The result from Step 2 is an n-by-n matrix representing a fully connected network that cannot be readily visualized. To extract structure from this data, we apply a couple of rules, i.e., firstly only those links between items should be displayed which have the highest similarity scores and secondly, the network should be connected, that is there should be no isolated nodes or disconnected clusters.

Step 4 is related to the layout and creating the network graph (shown in Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.). The similarity score calculated in the previous steps is imported to Gephi[1]. Gephi is an open-source network analysis and visualization software package.

In order to rank the standards, some indicators are calculated within the Gephi tool such as degree centrality, eigenvector centrality, etc. For this representation of the analysis we use two such indicators, namely, the document centrality and the degree centrality. While the indicator "degree centrality" measures the number of out-going links for each standard for a time period, "document centrality" is a measure defined and proposed in our previous article (Klimek, Jovanovic, Egloff, & Schneider, 2016) that is similar to the well-known centrality measures, such as eigenvector centrality, Katz prestige, or PageRank (Sharma, Jain, & Aggarwal, 2018). While the usual centrality measures typically do not depend on which kind of terms overlap between two documents, "document centrality" does and a document is regarded as ''central'' if it contains a large number of terms that commonly appear together with other terms, which in turn appear in a large number of other documents.

The recursive nature of this measure can be expressed as the fact that a document is ''central'' if it is linked by central terms to other documents that are also regarded as central. This measure combines two indicators: The first indicator estimates the number of different terms in a given document. It can be interpreted as the degree (number of links) of a document in the bipartite network of the term–document matrix. While this indicator is in a sense ''blind'' to which terms co-appear in the document, this is not true for the second indicator that can be interpreted as a recursive centrality measure for bipartite networks. The method computes the bipartite centrality measures that adapt the conventional recursive centrality measures on networks (such as Katz prestige, eigenvector centrality, or Google's PageRank) to the bipartite situation. The eigenvector centrality is generally considered to be a measure of the "influence" of a node in a graph: the more

[1] https://gephi.org/

central a node is, the more central its neighbours are and so forth similar to page ranking of web search engines (e.g. Google search).

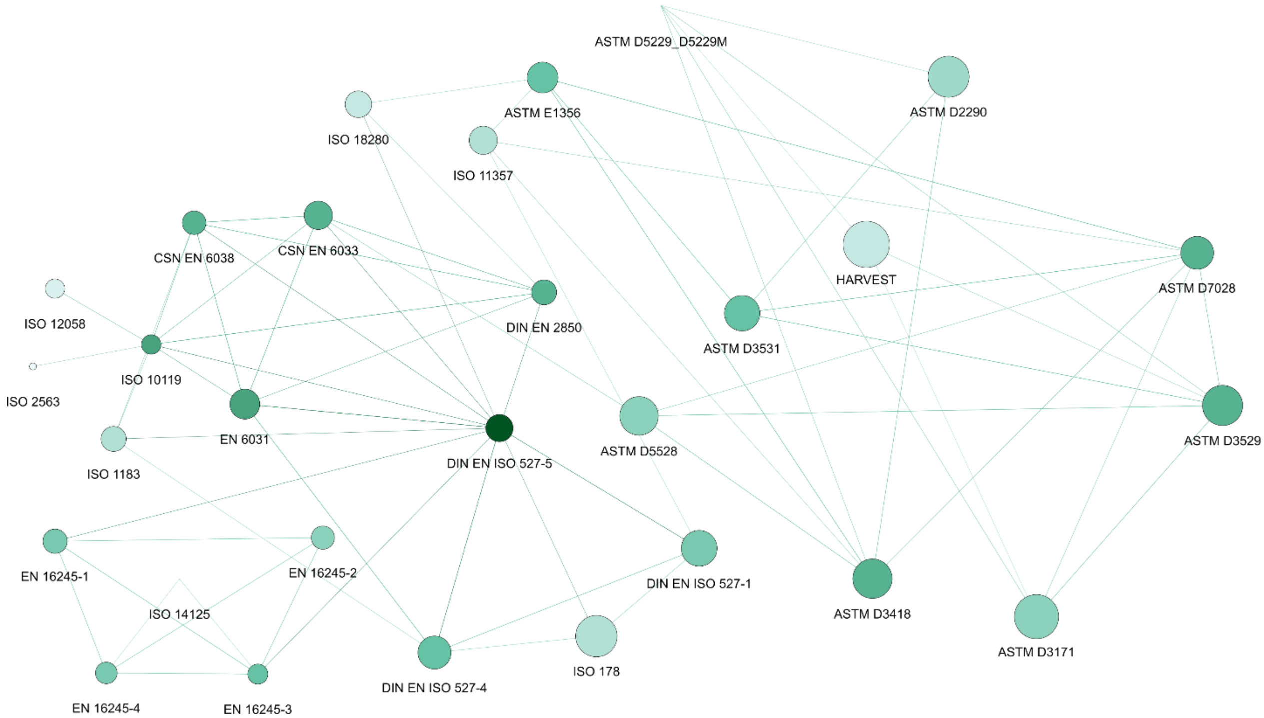

Figure 1: Semantic similarity analysis of HARVEST project and related standards

Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε. shows the network graph obtained from the analysis. The node (circle) size shown is proportional to its document centrality with increasing node size indicating a higher value for document centrality. The colour indicates the node's degree. Higher values of degree centrality correspond to documents that contain a large number of keywords that appear in a high number of other documents whereas low values indicate that the document contains highly specific terms that are used in few other documents.

As depicted by the graph, **the node size of HARVEST (0.89348) is the largest among other documents which indicates the project's central role integrating concepts from different standards**. On the other hand, the standard DIN EN ISO 527-5 (Plastics — Determination of tensile properties — Part 5: Test conditions for unidirectional fibre-reinforced plastic composites) was found to have the highest degree centrality (15), represented in **Figure 1** with the deepest green colour indicating that it has the highest degree centrality and thus, presents more connections to the other standards.

A list of these standards alongside with their Document Centrality and Degree Centrality is presented in **Table 1.**

It has to be noted that the selected list is not exhaustive as more standards exist in the field. However, the most relevant standards were selected for this analysis.

Considering the values of the Document centrality it can be seen from **Table 1** that, apart from the title and abbreviation of the project, which was included in the analysis, the most general standards that are used for evaluating the composite physicochemical and mechanical properties have the highest Document centrality values. This is partly because they contain the largest number of terms that are appearing also in other standards but also because they represent baseline documents for material characterisation. On the other hand, when moving to more specialised methods of materials characterisation, like Hydrothermal ageing that is covered by the ASTM D5229_D5229M, the values of the document centrality become lower.

Considering the values of Degree centrality the standards that contain the most complex characterisation methods that require referencing to other more basic standards seem to present the highest degree centrality values.

Table 1: List of standards that were used for semantic analysis

Standards's abbreviation	Standard's title	Document Centrality	Degree Centrality
HARVEST	Hierarchical multifunctional composites with thermoelectrically powered autonomous structural health monitoring for the aviation industry	0.89348	3
ASTM D3171	Standard Test Methods for Constituent Content of Composite Materials	0.8698	6
ISO 178	Plastics — Determination of flexural properties	0.83845	4
ASTM D2290	Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe	0.83517	5
ASTM D3529	Standard Test Methods for Constituent Content of Composite Prepreg	0.8242	9
ASTM D3418	Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry	0.81563	9
ASTM D5528	Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites	0.80601	6
DIN EN ISO 527-1	Plastics — Determination of tensile properties — Part 1: General principles	0.77437	7
ASTM D3531	Standard Test Method for Resin Flow of Carbon Fiber-Epoxy Prepreg	0.77106	8
DIN EN ISO 527-4	Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites	0.74309	8
ASTM D7028	Standard Test Method for Glass Transition Temperature (DMA Tg) of Polymer Matrix Composites by Dynamic Mechanical Analysis (DMA)	0.74126	9
ASTM E1356	Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry	0.71713	8
EN 6031	Aerospace series - Fibre reinforced plastics - Test method - Determination of in-plane shear properties (± 45° tensile test)	0.70717	10
CSN EN 6033	Aerospace series - Carbon fibre reinforced plastics - Test method - Determination of interlaminar fracture toughness energy - Mode I - GIC	0.68906	9
ISO 11357	Plastics — Differential scanning calorimetry (DSC) — Part 1: General principles	0.6873	4
DIN EN ISO 527-5	Plastics — Determination of tensile properties — Part 5: Test conditions for unidirectional fibre-reinforced plastic composites	0.67593	15
ISO 18280	Plastics — Epoxy resins — Test methods	0.66907	3
ISO 1183	Methods for determining the density of non-cellular plastics	0.65171	4

DIN EN 2850	Aerospace series - Carbon fibre thermosetting resin - Unidirectional laminates - Compression test parallel to fibre direction	0.65101	9
EN 16245-1	Fibre-reinforced plastic composites - Declaration of raw material characteristics - Part 1: General requirements	0.64328	7
CSN EN 6038	Aerospace series - Fibre reinforced plastics - Test method - Determination of the compression strength after impact	0.63549	9
EN 16245-2	Fibre-reinforced plastic composites - Declaration of raw material characteristics - Part 2: Specific requirements for resin, curing systems, additives and modifiers	0.63044	6
EN 16245-4	Fibre-reinforced plastic composites - Declaration of raw material characteristics - Part 4: Specific requirements for fabrics	0.61287	7
EN 16245-3	Fibre-reinforced plastic composites - Declaration of raw material characteristics - Part 3: Specific requirements for fibre	0.59443	8
ISO 10119	Carbon fibre -Determination of density	0.58731	10
ISO 12058	Determination of viscosity using a falling-ball viscometer-Part 1: Inclined-tube method	0.58596	2
ISO 2563	Aerospace series - Carbon fibre reinforced plastics - Unidirectional laminates - Flexural test parallel to the fibre direction	0.44637	1
ISO 14125	Fibre-reinforced plastic composites - Determination of flexural properties	< 0.4	2
ASTM D5229_D5229M	Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fibre Reinforced Polymer Matrix Composites Hydrothermal ageing via moisture absorption under environmental loading	< 0.4	6

3 GAP ANALYSIS

3.1 RESULTS AND STATISTICS

The gap analysis for HARVEST was performed by means of a survey which was designed and submitted online to the consortium members to evaluate three factors:

- Applicability of the identified European, American and International standards in different parts of the project
- Familiarity of HARVEST partners with the standards relevant to their tasks
- Coverage of different tasks with the existing standards

The survey contained 10 questions as described in Appendix 1, with the possibility of multiple choices for each question. Based on the analysis from this survey, **Figure 2** shows the familiarity of the partners with the standards relevant to their activities in HARVEST. As this graph depicts, most of the partners (73%) are perfectly aware of the application of standards related to their work.

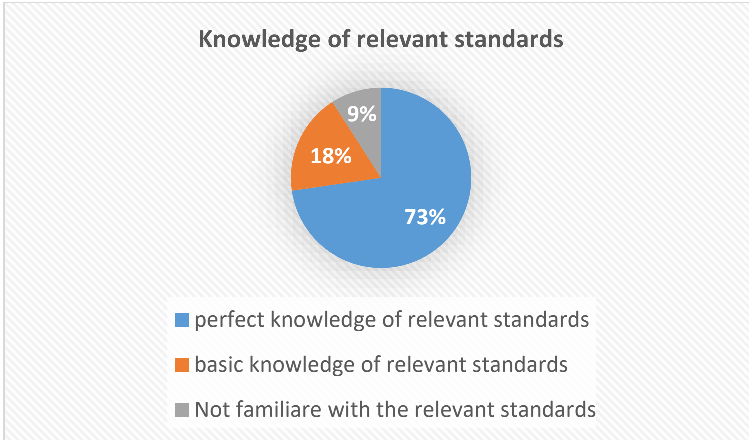

Figure 2: Familiarity of partners with the standards

The survey results also demonstrated that among the general standards, ISO 9001 (Quality Management) is used by most of the partner organizations while ISO 31000 (Risk Management) is used only by 3 out of 11 consortium members followed by ISO 14040/14044 (Environmental Assessments) considered only by 1 partner. ISO 14001 (Environmental Management), ISO 45001 (Occupational Health and Safety) and OHSAS 18001 were other standards which were not mentioned previously but the results show that some of the partners are using these standards within their organization. **Figure 3** shows the application of these general standards among the consortium members.

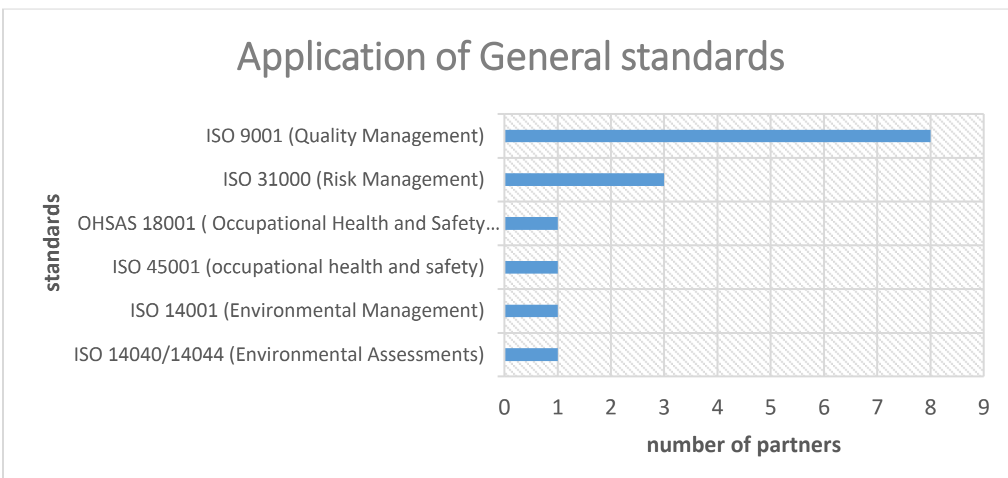

Figure 3: Application of General standards among partner organizations

In case of technical standards on the other hand, **Figure 4** depicts that the related American standards and International (ISO) standards for plastics have been used more often in the project. When it comes to the European standards, **Figure 5** indicates that only a few number of partners have considered these standards in their tasks. Therefore, as the results demonstrate, use of technical standards in HARVEST is not limited to the European standards. Other technical standards were further recognized during the gap analysis and are mentioned in the next chapter of this report.

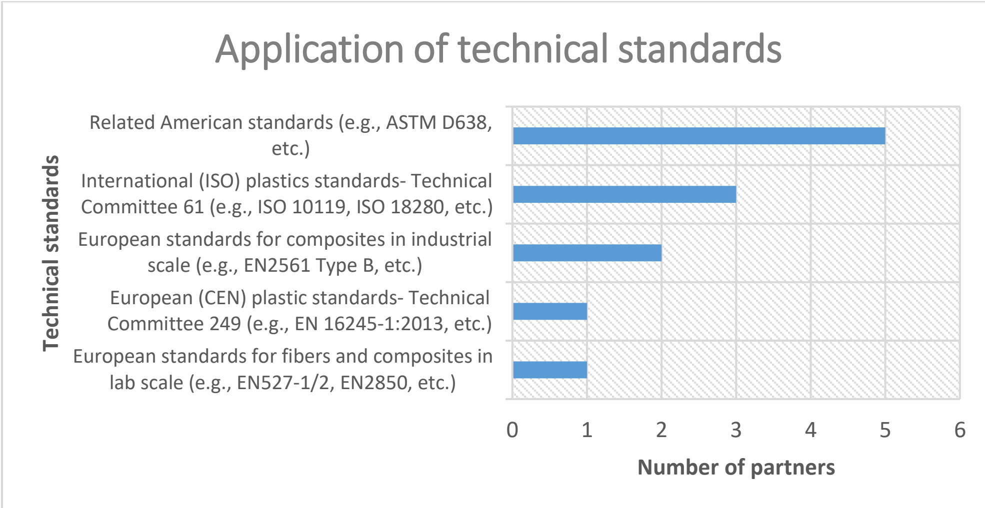

Figure 4: Use of technical standards relevant to the project

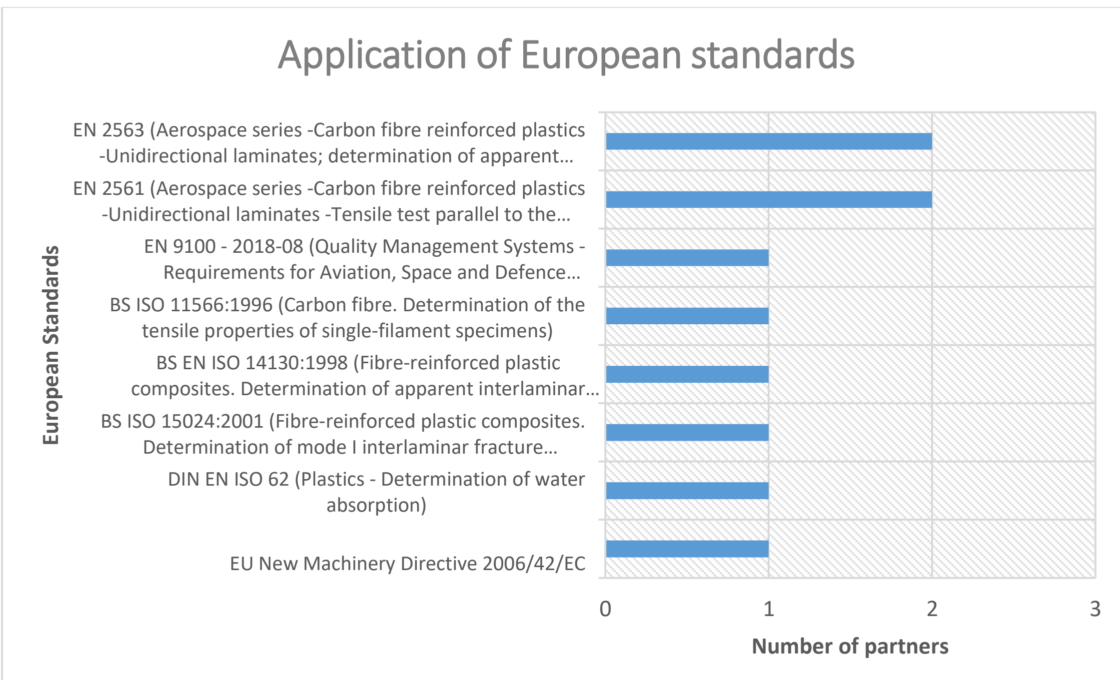

Figure 5: Use of identified European standards in the project

3.2 STANDARDS IDENTIFIED IN GAP ANALYSIS

In the previous section, the applicability of identified standards in practice was discussed alongside with awareness of consortium members of the relevant standards. During the project, both European and the respective American standards were utilised by the consortium depending on the availability of and familiarity with the standards in each organization Table 2 indicates a list of these newly identified standards and their applications in HARVEST.

Table 2: Identified standards through the survey results analysis

Standard	Application
ISO 14001	Environmental Management System
ISO 45001	Occupational Health and Safety Management System
ISO 527-2	Determination of tensile properties
ISO 178	Determination of flexural properties
ASTM C1557-20/ ISO 11566	Fiber Tensile Tests
ASTM D2344/ BS EN IASO 14130	Standard test method for tensile strength and Young's modulus of fibers ILSS or Short Beam shear
ASTM D5528/ ISO 15024	Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates Mode I
ASTM D5229_D5229M	Standard Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fibre Reinforced Polymer Matrix Composites Hydrothermal ageing via moisture absorption under environmental loading
ASTM D3531	Test method for resin flow of carbon fiber-epoxy prepreg
ASTM E1356	Test method for assignment of the glass transition temperatures
ASTM D3418	Test method for Transition Temperatures and Enthalpies of fusion and crystallization of polymers
ASTM D3529	Test method for transition temperatures and enthalpies of fusion and crystallization of polymers
ASTM D3171	Test methods for constituent content of composite materials
ASTM D7028	Test method for glass transition temperature (DMA Tg) of polymer matrix composites by dynamic mechanical analysis (DMA)
EN 9100	Quality Management System for the aerospace industry
European Cooperation for Space Standardization (ECSS)	for ground support equipment
OHSAS 18001	Occupational Health and Safety Management System
Aeronautic/Airbus standards (e.g. AITM series)	Different test methods
EU New Machinery Directive 2006/42/EC	Safety in machinery

3.3 IDENTIFIED GAPS IN THE PROJECT

One of the main objectives of gap analysis is to find the activities within the project for which no standard has been developed. This could be also one of the most important outcomes of this report since it indicated the need for development of new standards in the future. A total number of four tasks were identified for which there is no standard guidelines. These include:

1. Development of inks with p- and n-type thermoelectric response by a combination of dispersion methods.
2. Coating of fibrous substrates for the development of hierarchical composites
3. Development of Thermoelectric Generator (TEG) modules and laminae involving the design, ink characteristics, adhesion properties of inks substrates, application/integration of the TEG to the composite flat laminates or composite parts with other shapes, electrical interconnections of the TEG.
4. Prepreg manufacturing by R2R process (both glass and carbon fiber prepreg), which is only partially covered at the characterization stage by the standards: ISO 8604, ISO 9782, ISO 10352, ISO 11667, BS EN ISO 12115, ISO 12114, ISO 15040 and ISO 15034

Moreover, two issues were described in the survey, one technical and one general, for which there is no explanation in the existing standards:

1. Low Seebeck coefficient with NC7000 hard upscaling dispersion with SWCNT NC7000 alone in epoxy resin was not enough, should pass by synergy with carbon black
2. Working in R&D in materials science always has the problem of not so well established manufacturing procedures. Working with novel materials in small quantities requires often to adapt manufacturing or processing procedures in several loops. This explains why material based innovations (from basic research to first industrial-standardized application) takes about seven years (from the experience of many R&D projects this seems to be some kind of a "constant" time)

The latter indeed, generalizes all R&D processes and not a specific standard can be identified to solve this issue. However, individual processes within the R&D procedure might be covered by the related standards.

3.4 BRIDGING THE GAPS

Bridging the gaps between research and marketable products/services requires further effort and interactions beyond the research activities. In this chapter, a pathway to analyze the standardization aspects of a research project and to draw its standardization strategy for bridging the standardization gaps is extracted from the literature (Sales, Darmois, Papadimitriou, & Bourse, 2012):

- **Step 1**: Identify what needs to be standardized to allow the technology proposed by the project to be interoperable and deployable at large scale. In general, this step implies the identification of an “initial” architecture. For this purpose, the gaps mentioned in the previous chapter can be considered as the production/test methods which need to be standardized.
- **Step 2**: Identify the role and impacts of standardization bodies on the business segment targeted by the project. At this step, standardization bodies are categorized as fulfilling a role in the standardization chain, i.e. requirements, architecture, solution/protocol/interface and interoperability/testing. This action has been implemented in the previous stage of standardization where the technical committees and standards relevant to HARVEST activities were recognized.

- **Step 3**: Evaluate the need to improve the standardization eco-system to maximize the chance of success, this can materialize either by creating new (pre-) standardization technical committee and/or by attracting major stakeholders. Such evaluation requires further efforts to introduce the project to the standardization bodies and stakeholders.
- **Step 4**: Identify the "structuring" dimensions (i.e. what characterizes the standardization objectives trajectory/path) for the proposed technology/system to define a) the criteria to shape the associated standardization target(s) of the research projects b) the necessary conditions to meet in order for the technology/system to enable its standardization. The output of this step is a standardization objectives trajectory to be realized.

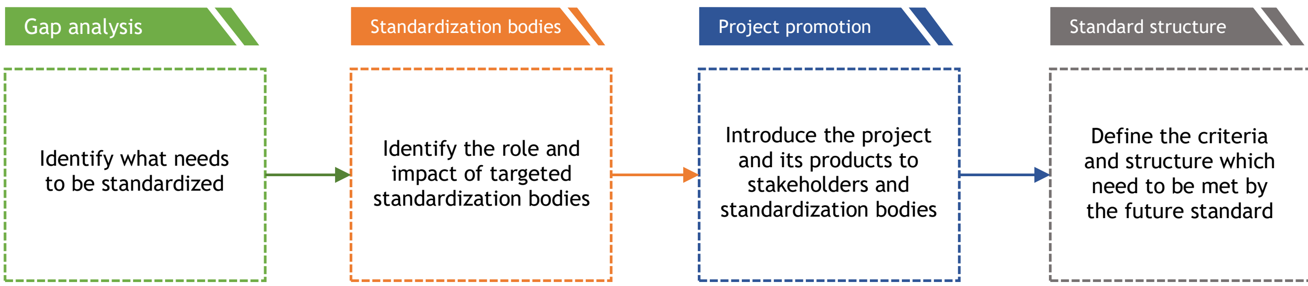

Figure 6: Proposed workflow to bridge the standardization gaps

This workflow, visualized in **Figure 6** needs to be structured through further development of the HARVEST objectives once the project outcomes are on their way to the market. This action is out of the scope of HARVEST project as it reaches up to TRL 4-5 (technology validated in lab or in relevant environment) and thus further developments are required to move towards a product that is ready for the market. However, such development requires close connection with the standardization bodies and authorities in order to a) present the products coming to the market and b) to describe the production and test methods which demand standard guidelines. To facilitate this process, the results from the standardization activities which are presented in this report as well as the previous deliverable, can be of a great benefit.

4 CONCLUSION

Through the current standardization task, more standards were recognized to be applicable in manufacturing and test methods of HARVEST project. Three partners have reported that they have encountered standardization gaps as discussed in section 3.3 of this report. However, some of these gaps reffer to the technical risks or delays which caused interuption in the technical work. The majority of the gaps were reported by UOI, which leads us to the conclusion that some activities such as prepreg manufacturing and development of structural materials lack comprehensive guidelines among the available standards or at least among the standards which were identified at the earlier stages of the project. However, as mentioned in previous chapters, most of the american standards have their equivalent amongst European or ISO standards but the survey results show that in most cases the american standards were used. Lack of standard guidelines for some activities in the HARVEST causes gaps between the developed methodologies, and marketable products.

Bridging these gaps on the other hand, requires close interactions between the project administrators and standardization bodies. The framework which was introduced in the last chapter of this report can be of advantage when it comes to bridging the gaps and developing new standards.

5 APENDIX

5.1 GAP ANALYSIS SURVEY QUESTIONS

Q1	Which processes are you involved in within HARVEST? (Multiple choices enabled)	
	Process	**Number of partners**
	Preparation of Epoxy Resin System	1
	Preparation of Masterbatch and Ink	1
	Coating of carbon fibers	2
	Filament winding process	2
	Preparation of prepreg at R2R line	2
	Development of electronics	1
	Manufacturing of composites	3
	Manufacturing of demonstrators	4
	Modelling activities	2
	Others	3
Q2	Which lab-scale tests have you been involved with? (Multiple choices enabled)	
	Lab-scale tests	**Number of partners**
	Single fiber tensile test	1
	Single fiber fragmentation test	1
	Tensile loading	3
	Filled hole tensile loading	1
	Compression loading	1
	Open hole compression loading	1
	In-plane shear loading	1
	Short-beam testing	4
	3-point-bending	1
	4-point-bending	1
	Mode I double cantilever beam	3
	Low velocity impact	1
	Compression after impact	2
	Cyclic loading	3
	Others	7
Q3	Which industrial-scale tests have you been involved with? (Multiple choices enabled)	
	Industrial-scale tests	**Number of partners**
	C1. Tensile Strength (0°) / (90°)	2
	C1. Tensile modulus (0°) / (90°)	1
	C1. Tensile strain (0°) / (90°)	1
	C3. Compression strength (0°) / (90°)	1
	C4. Compression modulus (0°) / (90°)	1
	C4. Compression strain (0°) / (90°)	1
	C5. In-plane shear strength / modulus / strain	1
	C6. ILSS	3

	C7. Flexural strength / modulus	2
	C8. Tensile strength / modulus / strain	2
	Others	1
Q4	Which of the following standards does your company/institute currently comply with? (Multiple choices enabled)	
	ISO standards	**Number of partners**
	ISO 9001 (Quality Management)	8
	ISO 31000 (Risk Management)	3
	ISO 14040/14044 (Environmental Assessments)	1
	Others	5
Q5	Are you familiar with the standards applicable to your tasks in HARVEST?	
	Response	**Number of partners**
	Yes, perfectly	8
	Yes, I have basic knowledge of relevant standards	2
	No, I don't know anything about applicable standards	1
Q6	Which set of the standards have you considered during your work in HARVEST? (Multiple choices enabled)	
	Standards	**Number of partners**
	European standards for fibers and composites in lab scale (e.g., EN527-1/2, EN2850, etc.)	1
	European standards for composites in industrial scale (e.g., EN2561 Type B, etc.)	2
	International (ISO) plastics standards- Technical Committee 61 (e.g., ISO 10119, ISO 18280, etc.)	3
	European (CEN) plastic standards- Technical Committee 249 (e.g., EN 16245-1:2013, etc.)	1
	Related American standards (e.g., ASTM D638, etc.)	5
	Others	7
Q7	Which European standards have you considered to support your tasks in HARVEST? (Multiple choices enabled)	
	European standards	**Number of partners**
	EN 14125 (Thermoplastic and flexible metal pipework for underground installation at petrol filling stations)	0
	EN 2561 (Aerospace series -Carbon fibre reinforced plastics -Unidirectional laminates -Tensile test parallel to the fibre direction)	2
	EN 2563 (Aerospace series -Carbon fibre reinforced plastics -Unidirectional laminates; determination of apparent interlaminar shear strength)	2
	EN 2850 (Aerospace series -Carbon fibre thermosetting resin -Unidirectional laminates -Compression test parallel to fibre direction)	0
	EN 6031 (Aerospace series -Fibre reinforced plastics -Test method -Determination of in-plane shear properties (± 45° tensile test))	0
	EN 6033 (Aerospace series -Carbon fibre reinforced plastics -Test method -Determination of interlaminar fracture toughness energy)	0
	EN 6038 (Aerospace series -Fibre reinforced plastics -Test method -Determination of the compression strength after impact)	0

	Others	9
Q8	How well do you think your current manufacturing or testing processes meet the relevant standards?	
	Response	**Number of partners**
	Extremely well	4
	Very well	6
	Only some parts	1
	Barely	0
	Not at all	0
Q9	In standardization, "gap" is defined as a difference between the real performance and desired (standard) performance.	
	Response	**Number of partners**
	Yes, in manufacturing processes	3
	Yes, in test methods	0
	No gaps observed	8
Q10	Please explain briefly at least 3 most important gaps that you have recognized in your work within this project	Answers are discussed in chapter 3.3 of this report

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