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Short communication

# Supporting the development process for building products by the use of research portfolio analysis: A case study for wood plastics composite materials

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ABSTRACT

Today's plastics are increasingly compounded using renewable fibres. Such composites raised the interest of the massively bulk-plastics consuming building industry. However, "green" products are still rare and their development constitutes a challenge particularly for small companies.

Our study evaluated European scientific projects in composites from which we derived a Research Portfolio serving as future matrix for ideation. It was found that research databanks can serve as basis for strategic innovation planning. We were able to identify several appropriate future technologies and material applications in the field of bio-based plastics composites. Our methodology particularly supports manufacturers with less formalized innovation processes.



## 1. Introduction

In times of increasingly scarce resources, conventional materials are being more and more treated with renewable ingredients. As composites, they offer the possibility to specifically produce desired or suppress adverse material properties. The so called "bio-fibre reinforced plastics" (WPC) play today an important role particularly in the gardening sector. They mostly consist of wood fibres embedded in a petrochemical matrix. By acting as reinforcement they increase the stability and stiffness of the composite material compared to pure plastics. In addition to this, they substitute up to 80% of the fossil-based polymers and therefore they relieve the pressure on fuel resources which are scares. Furthermore, they offer the potential of being completely substituted by pure bioplastics which turns them into green-composites.

The most important WPC sector is the construction industry with decking, wall panels and fencing and automotive with interiors. The European market for WPC is expected to increase from 220,000 t in 2010 by 60% to 350,000 t in 2015. The highest growth rates are in the scope of decking. Their production volume in 2012 was 174,000 t which amounts to 67% of the total of WPC [1]. Other applications in the construction industry are cladding and fencing. Their share of the total European WPC production was in 2012 only 6.1% and it can be theorized that particularly cladding is still in its infancy.

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In terms of biopolymers, only throw-away packing counts to their target applications and as far as bio-fibre reinforced bioplastics (i.e., green-composites) are concerned, there are yet no remarkable products used in buildings. After all, the literature reviewed on product development sees, particularly in the construction industry, an increasing interest primary in ecological aspects given by WPC [2]. Chabba and Netravali [3] recognized in today's WPCs the potential for a further substitution of the fossil-based plastics matrix by biopolymers, for instance, WPC as the next generation. Taking into account, that these composites already show well developed properties, it is now up to the plastics consuming construction industry to identify appropriate applications and to convert them into high-profit products.

Due to the diversity of the fields of view for possible WPC trends and the required in-depth knowledge of material technology, customer preferences and development processes, we precociously noticed a need for reliable information sources containing already compressed data about future developments in WPC. For medium sized enterprises it is far more important that this data can be generated by the company's management within a reasonable cost and time frame. Assuming that R&D projects are based on an anticipated potential analysis, our study is the first to examine the use of project databases as an information pool about trends and future developments in WPC with respect to the construction industry. Our approach is explorative by nature and it is based on a meta-analysis of research projects ($P_{tot} = 67$) in the field of bio-fibre reinforced plastics. We derived from it a project-based future matrix by explaining current WPC developments in the light of the *Technological S-Curve* concept to Foster (McKinsey). This method predicts whether a specific research area is still in the phase of generic research or already close to commercialisation. Findings are in the interest of the bio-plastics industry and particularly of the medium sized European WPC companies which will be enabled to easily gather significant input for their corporate innovation roadmap.

## 2. Theoretical framework

What new innovations and what their contribution will be, as to achieve the strategic objectives, is a question which must be answered by the innovation management prior to product development. The Organisation for Economic Cooperation and Development (OECD) sees in research and development an important ingredient for innovation. The Fracsati Manual [4] from the OECD defined R&D as " . . . *a systematic work process which generates new knowledge*". Depending on the degree of integrating research into practice, the OECD distinguishes between three activities, namely *Basic Research,* which is used to gain knowledge without seeking a specific application or implementation, and *Applied Research*, which findings focus on practical applications or implementations. Finally, there is *Experimental Development*. Findings from this research are used to optimize either existing materials, products, processes or to create new products.

With regard to future innovations in the field of WPC, possible developments must possess a degree of novelty. They can come from generic developments or aligned to a specific customer need in the marked. Research in this scope is either fundamentally, application-based or driven by experimental development. Depending on the innovation idea, the management must identify potential fields of WPC or green-composites and should make a reliable estimate about the future market potential. Schuh [5] recommends for successful product development a systematic approach in generating ideas which he aligns to future trends. Eversheim [6] compares the search for innovation ideas with a filter, screening data from a trend analysis on their innovation potential and aligning them with the implementation capacity of the company. The various stages in the development process must be supported by appropriate analysis and assessment. These include so-called *matrices*. Brandenburg [7] used them in a 2-step approach to innovation ideas: (1) *Future Requirements* are identified based on trends and developments within the business environment. For this purpose, an initial *Future Matrix* weighs the identified trends and assesses their compliance with strategic business areas of the company. Schuh [5] refers to this applying a *Context Matrix* for a fictive future projection using the dimensions "future trends in the market" and "development areas of the company". Information derives from creative processes or from a continuous monitoring within the considered scope. (2) Those innovative ideas, showing the maximum fit to the company's strategic orientation, are subsequently elected. This is done in a so-called *Opportunity Analysis*. Finally, the most appropriate innovation idea is represented in a strategic target portfolio in the mix with already existing products of the company.

This study sheds the light on the application of databases about current WPC research projects from institutes and companies as an appropriate and suitable source of information about ideas on future innovations. Research and development is a costly undertaking for companies. It can be theorized that, with increasing industry participation, a quantification of the existing market potential or appropriate target group analysis were already anticipated in these projects. Thus, industry-related research at this stage includes a specific market demand as described by Paulukuhn [8]. Data about it could act as necessary input particularly for companies with a *Follower Strategy*. This data just has to be interpreted and processed by an analysis assessing the company-fit. But also generic research can serve as a starting point for further applied sciences. In particular, companies with a *Pioneering Strategy* can derive appropriate innovation ideas from this kind of research.

We also theorize that the use of evaluation matrices, as proposed by Schuh [5], is a suitable tool for ideation by data assessment. Within the generation phase, they support the identification of potential trends in future developments of WPC or green-composites. They can then be used as input for a *Future-Matrix* proposed by Brandenburg [7].

Based on the previous statements in composite technology and innovation management we hypothesize the following in terms of ideation in WPC development:

**H**: research project data banks are an appropriate source which supports ideation in an innovation management process about future products and technologies in a considered scope. From the findings, appropriate input data can be derived and processed to subsequent opportunity analysis.

Our hypothesis is subject of a validity proof for which this paper introduces a suitable design and exercise using the example of WPC and green-composites.

## 3. Research method

Evaluation of data about future trends should, in our opinion, be carried out by a matrix building a bridge to the *Context Matrix* proposed by Schuh [5]. We suggest using the dimensions "*customer- or industry-oriented*" set out by Paulukuhn [8] and "*application-oriented*" according to the Frascati Manual [4] and which supports the integration of the Technology-S-Curve concept to our design. Unit of analysis are objects and as such projects which carry information on research activities.

In the common literature the S-Curve concept is chosen to explain innovations and to plan technology development. Also we interpreted our results of the Project Matrix in the light of this concept and for a better understanding we defined a basic WPC research-life-cycle (Fig. 1) supporting the design of a significant Research Portfolio matrix.

The application of the S-Curve within WPC ideation supports the deductive concluding from the results of our Research Portfolio which lead to a forecast of future trends in materials and applications. We applied these basics in innovation management in a broader perspective by gathering information from a cross-sectional study of research facilities in the German-speaking countries (Germany, Austria and Switzerland). Within this meta-analysis we could identify 67 research projects over the past 5 years. For information processing our study employed a *Project-Matrix* with the two dimensions ($\upsilon$) and ($\zeta$), similar to the *Context-Matrix* introduced by Schuh [5]. Information transfer was supported by the indicators $I_{\text{res}(\upsilon;\zeta)}$ within a *Research Portfolio* comprising the quadrants I–IV in analogy to the *Technology-S-Curve* concept.

## 4. Case study findings and discussion

We thus turned our WPC Project-Matrix into a 4-field matrix which we called the *Research Portfolio* of WPC (Fig. 2). Each field is described by the variables *Industry Orientation* ($\upsilon$) and *Application Orientation* ($\zeta$) which provide information as to whether their assigned areas of research are more likely in fundamental or applied research and how intensively it is carried out ($I_{\text{res}(\upsilon;\zeta)}$).

Our matrix is divided into 4 quadrants, we call them fields of research, based on the previously discussed basic processes for WPC product developments according the Technology-S-Curve. The individual quadrants are: (I) *Generic basic research in WPC*; (II) *Basic Research* but with *incremental* character; (III) *Basic Applied Research* and (IV) *Incremental Applied Research.*

We conducted the following interpretations from the portfolio:

- Our *Research Portfolio* on WPC projects is mainly dominated by basic research with industry-related topics in the categories *Compounding* and *Material Properties* (59.71%). Research on WPC product application is comparatively inferior (10.5%). An explanation for this could be, that most of the Applied Sciences in WPC is performed at the manufacturers R&D laboratory and data about it is hardly published in our applied data banks. However, according our previous studies, WPC manufacturers still offer far little information about their product properties which underlines the low share of product-

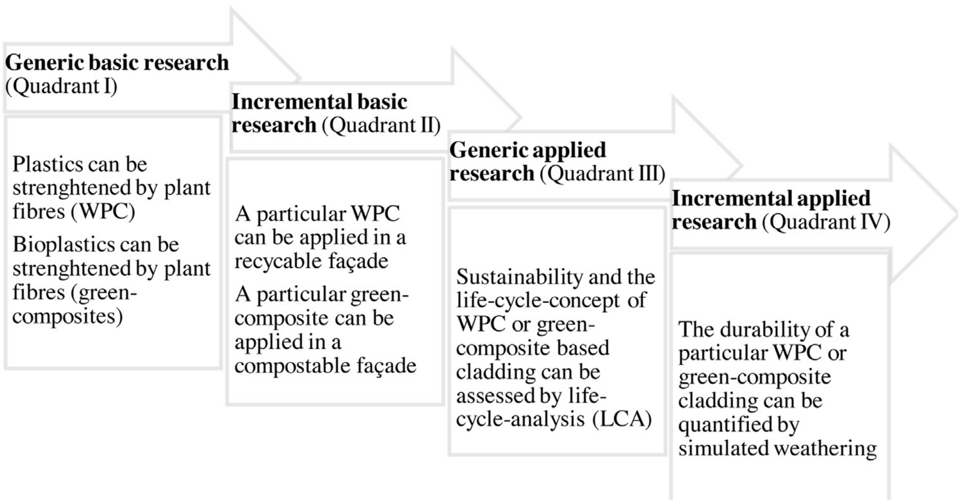


**Fig. 1.** Generic (I + III) and incremental (II + IV) development of WPC-products using the example of WPC or green-composite processed to cladding.

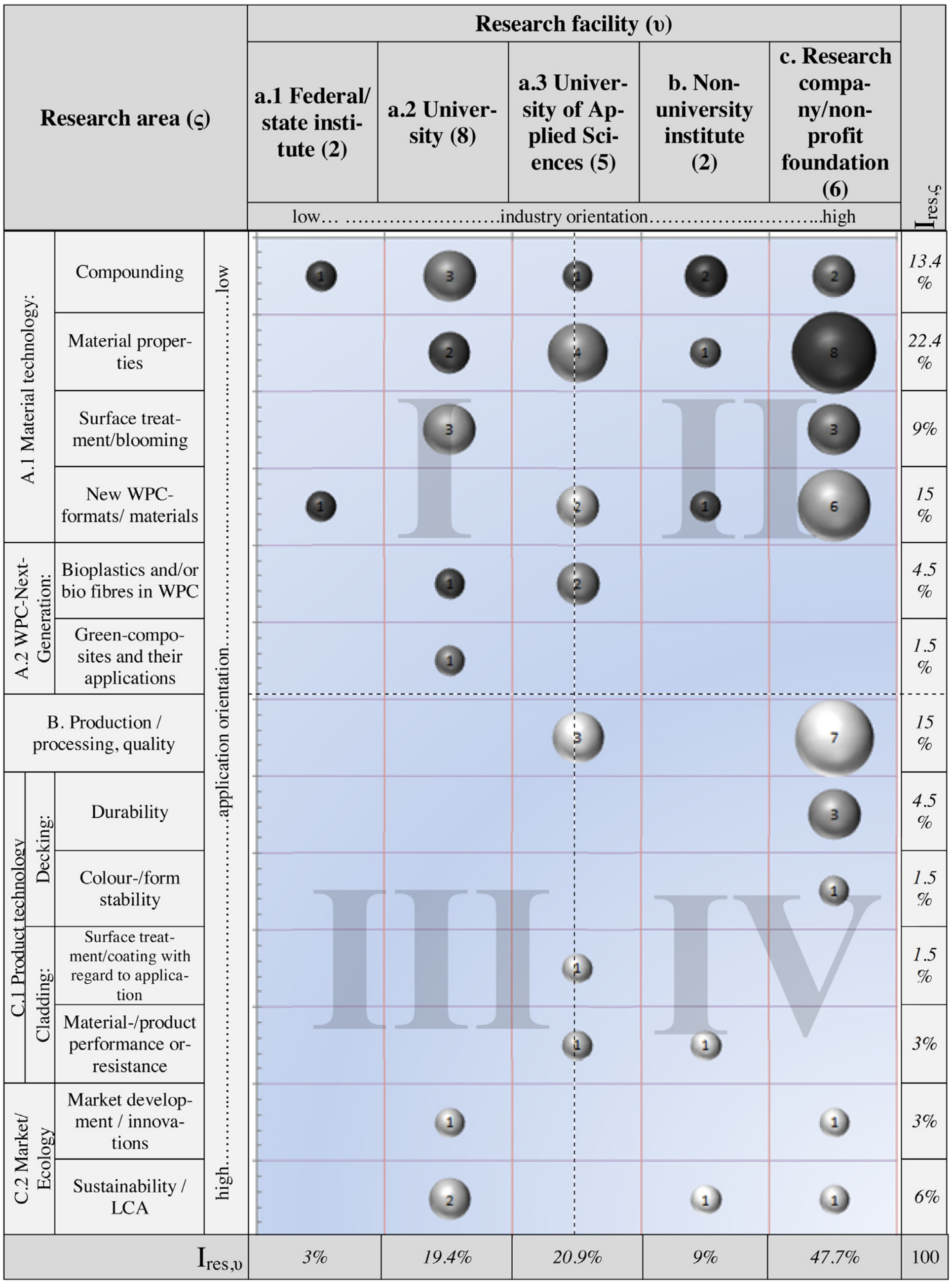


**Fig. 2.** WPC research portfolio as 4-field matrix.

related research. In addition to this, post research has found that most of the WPC manufacturers are medium sized without any significant research facilities. A strong argument can be made, that the WPC industry is already in the early state of incremental basic research. Hence, the WPC industry is still preoccupied with the material itself than with its use in products. Obviously, besides decking no more high-turnover products are to be expected in the near future although the state of the art, particularly in WPC and partly in green-composites, in this early state theoretically serves as successor technology with potential for ideation. We theorize from this that particularly small and medium sized companies (SME) need practical instruments for ideation.

- The *Next Generation* of WPC is apparently of small interest for the industry which is indicated by the fact, that only Universities and Universities of Applied Sciences consecrate themselves to this sustainable material. Also here we theorize that green-composite development is approaching faster than its implementation in the market based on products which are to be invented by the industry. The fact, that green-composites are still in the state of generic research, speaks for a

forthcoming shift towards incremental generic research, as happened to WPC, whenever their properties show feasible applications in the building industry. This explanation underlines the findings of Chabba and Netravali [3] and Carus and Eder [1] who all attest current WPC a high potential for "greening" its image. Here we come to full circle with our theory that green-composite material technology could serve as next successor technology for WPC.
- Only 34.2% of all projects are application-oriented. Some 15% dealt with manufacturing and 10.5% with product technology, as decking (6%) or cladding (4.5%). 3% studied the market development and 6% the ecological potential particularly of WPC decking under life-cycle considerations. Participating research players were exclusively Universities and Universities of Applied Sciences, whereas the industry is though mostly involved in manufacturing issues. Hence, our results support the work of Carus and Eder [1] who see the highest growth rates in decking rather than in cladding. Obviously, current WPC cladding does so far neither play an active role in research nor in sales.

In conjunction with the research topics, the portfolio can provide information on future innovations when combining findings about novel technologies and materials. We were able to select the following innovative ideas:

### *4.1. Innovations with radical potential*

- Quadrant I—material technology/compound: a significant proportion of university generic basic research is undertaken in *WPC Flat-Panels*. Established by flat pressing technology using dry-blends, they offer an interesting potential for market innovations, such as cladding panels or shingles made from current WPC compound.
- *Quadrant I—WPC next generation:* the basic research on pure bio-based fibre-reinforced plastics is already underway and constitutes a high potential for sustainable and compostable mass products. It could offer, just to the construction sector, an interesting field for radical innovations with considerable market success. This is due to legal proof of resource use and sustainability of building products (Regulation (EU) No 305/2011) [9]. Particularly engineers, seeking materials made from renewable resources, will be enabled to realise green building projects [10].

### *4.2. Innovations with incremental potential*

- Quadrant III—virtual product components for sales promotion: nowadays, applied basic research is executed under scientific methods focusing mainly on eco-balance and the derivation of appropriate life-cycle concepts for existing WPC product groups. Thus, this kind of research is in line with the increasing statutory demand for sustainable resource use. Such activities have only little innovative character but results can be used in sales promotion and for product differentiation. We strongly assume that, with increasing market growth of WPC cladding, the demand for such proofs will rise similar to decking.
- Quadrant IV—incremental product developments: we identified a strong industry involvement in the categories *Durability* and colour/form *Stability* of current WPC decking. We presume that, with increasing market saturation of today's WPC decking products, there is a need to stimulate demand again based on product variation, such as new shapes, dirt-repellent surfaces, structural use or even a clever recycling concept for cascading. Results therefrom are not very innovative but they serve the industry with a promotional and differentiation potential.

As illustrated by our WPC ideation case study, a Research Portfolio provides innovation ideas for products with both radical and incremental potential. Thereto we structured data according criteria which support the interpretation in the light of the Technology-S-Curve. The question to whether research findings are close to commercialisation is discernible by both the degree of industry participation and the application orientation. We were also able to identify green-composites as close to being a successor technology for future WPC products. Data was easily gathered by online data banks and their processing into a project matrix solely demanded a grouping and calculation of the corresponding intensity ratio. Results were arguably significant which is why we see our hypothesis confirmed by the research portfolio.

## 5. Conclusions

In a wider context, our WPC research portfolio classified current WPC research predominately being in the state of incremental basic material research. WPC actually represents a successor technology for outdoor applications in the building and gardening industry. In addition, applied research with focus on products is still in its infancy and so far solely based on decking. As this material technology is not sufficiently diversifiable, the development of further applications in the building scope obviously seems to be limited which hinders the identification of potential further mass products. A positive signal is sent out by research in green-composites. The substitution of the petrochemical polymer matrix already spreads out in the state of generic basic research. Not yet acting as successor technology, this field shows a promising potential to become further developed by incremental basic research which will advance towards Quadrant II in our research portfolio. We interpret this as one step behind a possible combination with current WPC and which speaks for a spread of potential future applications.

The obviously subordinate applied research in WPC is witness of decking and cladding being in the state of market growth where yet manufacturers are less under pressure for differentiation. Market saturation is thus not yet achieved. With a rising share of applied WPC research linked to products, this threat will surely come closer. Whenever WPC material recipe reveals a wider range of adjustable features, this composite might then serve as key technology which will enable multiple product variation of existing decking and cladding as well as diversification, e.g. cladding sub-construction made from WPC either.

Although today's WPC research shows activities in both technical and ecological aspects, our portfolio did not undermine a potential trend in the combination of these, such as an eco-innovation approach. Obviously, manufacturers still focus on mechanical material and product properties rather than on ecologically driven sales arguments, i.e. cascading or sustainable disposal. Research in this field is solely driven by public institutions and is therefore in the generic state similar to green-composites but with orientation to applications. However, according to our portfolio methodology, we expect that with ongoing activities therein, the industry will become increasingly interested in findings which might promote future product developments in the light of eco-assessments. This will affect the innovation management process of WPC to the extent that already in the phase of ideation a holistic view of the future product life-cycle should get institutionalized by the management.

Our case underscores the importance of a WPC Future-Matrix derived from current research projects. This result has a managerial implication because this method is useful for generating ideas for a strategic innovation roadmap. Besides our previous findings about the product technology life cycle of current WPC and its products, our matrix revealed a significant future trend in product innovations. This is given by generic research activities in the category "Material Technology—new WPC Formats". Here, we identified *WPC Flat-Panels* as a potential future product which fulfils the criterion for a pioneer strategy. In terms of green-composites and eco-assessment we conclude, that a WPC manufacturer who focuses on the development of a flat pressed green-composite façade panel will by doing so combine those trends according our portfolio which show the most significant innovation potential. This would satisfy the demand for more green products described by Charalampides et al [10]. In the second step, according Brandenburg [7], this idea should be balanced with the company's potential for its realisation. Alternatively, the risk given by green-composites not yet being in the state of a successor technology for the building scope can be omitted by using current WPC recipe. If then a significant market potential combined with a skimming pricing policy and an early break even for the development investment sounds realistic the innovation management could be well advised to realize this idea for which we assume a potential for radical innovation. Although, according Chabba and Netravali [3], the substitution of current plastics by biopolymers in today's WPC sounds also innovative, we would not by today interpret a green-composite decking as a radical innovation. We base our assumption on the fact that according our portfolio this kind of "WPC Next Generation" is still in the state of generic basic research for which Paulukuhn [8] typically sees not yet an industry involvement and by far no customer need. In combination with an existing product, e.g. decking, this idea would support a differentiation strategy which, in our view, might not justify a higher price level compared to current WPC decking. Biopolymers are not yet competitive to bulk plastics. Such an idea would demand a new target group which thoroughly has to be assessed in advance.

In closing, an added limitation of our study is related to the restriction of data which in our case came from German, Austrian and Swiss research projects and therefore they speak for a well-defined but narrowed geographical origin.

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