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BARRIERS TO THE IMPLEMENTATION OF KEY ENABLING TECHNOLOGIES

IZAZOVI IMPLEMENTACIJE KLJUČNIH RAZVOJNIH TEHNOLOGIJA

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Original scientific paper

Abstract: *Key enabling technologies (KET) are often crucial technological prerequisites for the advances in the production processes and product quality. They are expected to impact the existing technologies by expanding their usefulness, to enable new technological approaches and to trigger wider applications in a number of industries. Enabling technologies often have no direct easily recognizable connection with the applications, which makes it difficult to even determine the relevant impact categories. In order to stay competitive, Europe has built a fund for enhancing the usage and production of KET [1]. Since these technologies are new and their impact on the industry is still not easily identified, more research is needed. A literature review revealed many obstacles in the KET-related manufacturing, which is why in depth interviews with companies are needed. A survey research was conducted in Croatia on the level of the adoption of KET, followed by a workshop with companies that use KET in order to identify the problems they came across during the implementation.*

Keywords: *key enabling technologies, KET, transfer of technologies, European manufacturing, survey, implementation problems*

Izvorni znanstveni rad

Sažetak: *Ključne razvojne tehnologije obično su tehnologije koje su nužne za rad drugih tehnologija, proizvoda i procesa. One utječu na postojeće tehnologije povećavajući mogućnosti proizvodnih procesa i poboljšanje kvalitete. Omogućavaju nove primjene postojećih tehnologija i primjene u brojnim drugim industrijama. Takve razvojne tehnologije obično nemaju vidljiv direktan utjecaj na primjenu pa ih je teško kategorizirati i pratiti. Da bi ostala konkurentna Europa je pokrenula fond čija je jedina uloga poticanje na snažniju primjenu spomenutih tehnologija [1]. Budući da su ove tehnologije nove, nema puno istraživanja na tu temu. Istraživanje literature pokazalo je brojne prepreke u prihvaćanju naprednih razvojnih tehnologija, pa se vidi potreba za dubinskim intervjuima i pokušaju kvalifikacija tih tehnologija. U Hrvatskoj je proveden upitnik o korištenju tih razvojnih tehnologija, a zatim je uslijedila radionica s poduzećima koja koriste razvojne tehnologije da se vidi s kojim izazovima su se susretali prilikom implementacije.*

Ključne riječi: *ključne razvojne tehnologije, KET, transfer tehnologije, europska proizvodnja, implementacijski problemi*

1. INTRODUCTION

Key enabling technologies (KET) are often crucial technological prerequisites for other technologies, products and processes which are expected to impact the existing technologies by expanding their usefulness, to enable new technological approaches and to trigger wider applications in a number of industries. They often have no direct easily recognizable connection with the applications, which makes it difficult to even determine the relevant impact categories [2]. Those technologies are in the nascent stage and there are many production challenges, dominantly the high production costs and the public's general reluctance to embrace an innovative technology without the real safety data [3]. Some speak of KETs as a new industrial revolution, because different laws of physics come into play. Traditional materials such as metals and ceramics show radically enhanced properties and new functionalities, and the behavior of surfaces starts to dominate the behavior of bulk materials, and whole new realms opens up. Contrary to the popular belief, in the field of only nanotechnology, many industries already produce or employ products which are either nano-sized or exploit the nano effects, and are generating substantial revenues [4].

Key Enabling Technologies (KETs) are nanotechnology, micro- and nanoelectronics, including semiconductors, advanced materials, biotechnology and photonics, and advanced manufacturing systems. Mastering these technologies might mean a shift to a low carbon, knowledge-based economy. KETs play an important role in the R&D, innovation and cluster strategies of many industries, and are regarded as crucial for ensuring the competitiveness of European industries in the knowledge economy [5]. KETs have recently become one of the “hottest” areas in research and development worldwide in terms of issued patents, and have also attracted considerable attention in the media and investment community [6]. To stay competitive, Europe has built a fund for enhancing the usage and production of KET [1].

KET is multidisciplinary and in order to apply it, knowledge from physics, chemistry, biology and other areas are needed. A second problem is that companies stick to their core activities and are reluctant to introduce new risky technologies. Such a mental picture coupled with a limited understanding of KET and how an enterprise could exploit KET explains the absence of the concepts. The situation is particularly difficult in small or less developed economies [7]. No single professional has all the necessary skills to bring a KET product to the market on his/her own. Furthermore, those in the scientific field generally lack the understanding or the business acumen required to convert technology into a commercialized product. On the other hand, investors want to get involved with the next big thing but generally lack the patience and technical expertise required in the development and evaluation of these KET-based products [6].

Although it is widely agreed that the emerging technologies such as nanotechnology, biotechnology, etc. will have increasing socio-economic impacts, there are significant boundaries in terms of available economic resources and social and political accountability (“value for money”). This has led to the necessity of setting research priorities not only at the macro-level (e.g. choosing between the broad fields such as biotechnology, nanotechnology, ICT, etc.) but also at the country (macro) level [8]. Countries and regions invest heavily in the selected KETs in order to become a global player in the field. Reports on abundant government funding in various regions are heavily cited. However, competing with the best in the globalizing world is a tough challenge even for large emerging countries. Small countries face even more challenges. Since it is extremely difficult for a country to achieve competitiveness in many industries, [9] it is proposed that a country makes a choice of industries with high impact.

KETs are potential economic engines that have the capability to become the basis for a regional and national job and wealth creation [10]. [10] researched only the nanocenters, which by their survey are growing, but those centers are dominantly scientific research centers. Only 3% of their responders labeled themselves as industrial centers. As far as the funding goes, those nanocenters were dominantly financed by national governments or in the EU by the FP7 or Horizon 2020 funding scheme [11].

However, the key point is getting revenues and competitiveness by using those KET technologies. In their technology strategies, governments so far point to a specific technology or technologies that they find to be the most relevant for their settings, and they write strategies and devise policies and based on them fund the research on selected technologies. Albeit, the dominant effects of such government schemes are the increased scientific publications by research centers (not companies), which is not that relevant to the industry. According to the research done by [12], companies are more interested in patents and conference participation. If positive effects are to be achieved, then the commercialization of KETs is important. Commercialization is the process of turning new technologies into successful commercial ventures, which may involve an array of professionals from technical, commercial, and economic background to successfully transform a new technology into useful products or services. So far commercial applications are in industries that usually generate high revenues, e.g. cosmetics, medicine, various coatings and powder used in textile or building. The majority of companies name the lack of funding as the main barrier to the application and commercialization of novel products. Moreover, for quality control, more sophisticated equipment is needed, e.g. microscopy (atomic force microscopy, transmission electron microscopy (TEM), and scanning electron microscopy; measurement of particle size and size distribution with light scattering (static and dynamic); analytical ultracentrifugation, capillary electrophoresis; analysis of surface charge or zeta potential; examination of surface chemistry by X-ray photoelectron spectroscopy or Fourier transform infrared spectroscopy; differential scanning calorimetry and X-ray diffraction, among others. Such analytical equipment and the performance of these checks are not just expensive, but also require trained personnel to carry out the analysis and interpret the results. This would substantially add to the cost of manufacture and would definitely deter a company from investing in the development of such a product. Even if the industry plans to outsource these analyses to other firms, it would still be expensive as each and every batch would have to be run through several tests and transported to the premises of the controlling institute/company [6].

The main objective of this work is to find out what the level of the adoption of KETs in the least advanced member of EU – Croatia – is. However, since Croatian manufacturing largely exports its products, it is hypothesized that there some level of adoption of these technologies will be found. After a survey that revealed that 28% of surveyed companies do in fact use some of KET technologies, a workshop was conducted in order to find out what their experiences, issues and problems regarding the implementation of KETs were. Moreover, during the workshop, some possible further actions in order to facilitate the transfer of KET technologies were revealed. However, in order to talk about KETs, it is first necessary to define them.

2. OVERVIEW OF THE KEY ENABLING TECHNOLOGIES

KETs are knowledge intensive and are associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. They enable the production of new products and therefore augment the competitiveness of a company and then of the region. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. KETs necessitate large investments, but those investments could bring positive effects in the long run [13].

The following section provides a brief description of the multidisciplinary characteristics of some KETs in the EU and explains why advanced materials, nanotechnology, micro- and nano-electronics, industrial biotech and photonics and advanced manufacturing systems have been identified as a priority to improve the European industrial competitiveness.

2.1. Advanced materials

Advanced materials technologies lead both to new reduced cost substitutes to the existing materials and to new higher added-value products and services. This will reduce resource dependency and environmental waste and hazards at the same time. Besides the costs of capital, expenditure on materials is the most important cost factor in high-technology related industries. They are of key importance for the competitiveness of the EU industry, especially since Europe is not well endowed with natural resources [13].

2.2. Nanotechnology

Nanotechnology is an umbrella term that covers the design, characterization, production and application of structures, devices and systems by controlling the shape and size at the nanometer scale. European SMEs using nanomaterials are mostly present in the automotive and medical and healthcare sectors, followed by energy. Within the medical system and healthcare, implants (44%), molecular diagnostics (28%) and drug delivery (27%) are the most important fields of application. Applications in the energy field are mostly related to energy conversion or production (66%), followed by energy saving (38%) and energy storage (28%) [13].

2.3. Micro– and nanoelectronics

Micro- and nanoelectronics deal with semiconductor components and highly miniaturized electronic subsystems and their integration in larger products and systems. Europe has a declining share of worldwide investment in microelectronics. From a total investment of €28bn in microelectronics in 2007, only 10% was made in the EU compared to 48% in Asia. Europe’s semiconductor market share has declined from 21% to 16% since 2000. However, total direct employment in microelectronics in Europe is over 110 000 plus 105 000 in equipment manufacturers. Europe has a number of dedicated regions with a critical mass and particular semiconductor competencies which are recognized world-wide. These clusters have access to the most advanced technologies and are the key assets for the European industrial competiveness [13].

2.4. Industrial biotechnology

Industrial biotech is the application of biotechnology for the industrial processing and production of chemicals, materials and fuels. It includes the practice of using microorganisms or components of micro-organisms such as enzymes to generate industrially useful products, substances and chemical building blocks with specific capabilities that conventional petrochemical processes cannot provide. There are many examples of such bio-based products already on the market. The most mature applications are related to the enzymes used in the food, feed and detergents sectors. More recent applications include the production of biochemical, biopolymers and biofuels from agricultural or forest wastes [13].

2.5. Photonics

Photonics is a multidisciplinary domain dealing with the science and technology of light, encompassing its generation, detection and management. The EU has strong positions in many photonics applications such as solid state lighting (including LEDs), solar cells, and laser assisted manufacturing. Photonics is a good example of an enabling technology, as there are around 5000 photonics manufacturers in Europe employing around 246 000 persons (excluding subcontractors) directly. In addition to that, the jobs of over 2 million more employees in the EU’s manufacturing sector depend directly on photonic products. Germany accounts for 39% of European production volume, followed by France and the UK (12% each), the Netherlands (10%) and Italy (8%) [13].

2.6. Advanced manufacturing systems

Advanced manufacturing systems denote the range of high technologies involved in manufacturing, leading to improvements in terms of new product properties, production speed, cost, energy and materials consumption, operating precision, waste and pollution management. This is especially relevant in capital intensive industries with complex assembly methods. They are needed to help create marketable knowledge-based goods and the related services (e.g. modern robotics). For example, the production and assembly of modern aircraft involves the whole spectrum of manufacturing technologies from the simulation and programming of robotic assembly lines to reducing energy and materials consumption. Other examples include intelligent control systems, automation for modelling and production. They can be applied in all manufacturing industries and form an important element in the supply chain of many high value manufacturing businesses [13].

These are only general descriptions of technologies, but in order to conduct a survey, a more detailed description of the technologies was necessary.

3. METHODOLOGY

The questionnaire was developed through a massive literature research dominantly on Status Implementation reports from the European Commission, on each KET field. Even though the complexity of each technology is described in the previous section, for the survey process it was crucial to extract the enabling technologies that might be used by manufacturing companies. The sampling procedure was facilitated by obtaining e-mail addresses from the Croatian Chamber of Commerce, and it covered the whole manufacturing sector with over 10 employees. 2037 addresses of manufacturing companies in Croatia with over 10 employees were obtained. It was believed that micro companies with less than 10 employees hardly use such sophisticated technologies. The survey was launched twice, once at the beginning of September 2014, followed by the next round in October 2014. Responders usually answered a couple of days after the launch of the survey. That enabled the checking of non-response biases, which is highly necessary in this study since the return rate was only 2%. The rate is truly small but as [14] shows, the response rates are almost linearly declining and therefore scientists more often than not engage in case study research. Moreover, such a small sample is due to the fact that KETs are still not in wide usage even in the advanced economies.

Richards et al. [15] have identified that there are both psychological and mechanical reasons for low response rates with web-based surveys. Psychological reasons include: people may have forgotten about it; they may be so busy that they do not want to take the time to fill the survey out; some people find surveys a disruption to their personal lives; or the survey is too long. Mechanical reasons may include a lack of Internet access, concerns with the security and data integrity, and technical problems and other reasons of unwillingness or inability to participate in the survey. Given these issues and generally low response rates with self-administered surveys, non-response bias is a significant concern and particularly salient for web-based research [16], [17]. Among various methods of checking for non-response biases described by [18], Wave Analysis was used, which consists of comparing late respondents to early respondents. Wagner and [19] cite [20] the rule of thumb as a minimal response rate of n=30. Our sample fulfils this minimal criterion, as 37 companies returned filled in questionnaires.

Since this is an extremely low response rate, it was necessary to check the representativeness of the sample according to the industry and size of companies. The calculation of representativeness by NACE codes is given in Table 1. The methodology used can be found in [21]. A group is considered representative if its Z value does not surpass 1.96 which is the critical value at 5% significance level, meaning that the null hypothesis that the sample represents the parent population can be accepted.

Table 1. Representativeness by industry

NACE code	Population	Sample	Z	Representative
10 Manufacture of food products	311	3	-1.44	Rep
11 Manufacture of beverages	50	0	0	
12 Manufacture of tobacco products	2	0	0	
13 Manufacture of textiles	55	0	0	
14 Manufacture of wearing apparel	139	2	-0.41	Rep
15 Manufacture of leather and related products	47	2	0.60	Rep
16 Manufacture of wood and products of wood and cork; except furniture; manufacture of articles of straw and plaiting materials	190	3	-0.34	Rep
17 Manufacture of paper and paper products	47	2	0.60	Rep
18 Printing of the reproduction of recorded media	95	1	-0.68	Rep
19 Manufacture of coke and refined petroleum products	2	0	0	
20 Manufacture of chemicals and chemical products	61	3	0.83	Rep
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations	15	0	0	
22 Manufacture of rubber and plastic products	144	3	0.08	Rep
23 Manufacture of other non-metallic mineral products	139	5	0.83	Rep
24 Manufacture of basic metals	36	0	0	
25 Manufacture of fabricated metal products, except machinery and equipment	364	2	-2.88	
26 Manufacture of computer, electronic and optical products	66	1	-0.23	Rep
27 Manufacture of electrical equipment	90	3	0.57	Rep
28 Manufacture of machinery and equipment n.e.c.	133	3	0.18	Rep
29 Manufacture of motor vehicles, trailers and semi-trailers	24	2	0.85	Rep
30 Manufacture of other transport equipment	52	0		
31 Manufacture of furniture	102	3	0.46	Rep
32 Other manufacturing	46	1	0.07	Rep

As it can be seen from Table 1, there are several industries that are not represented. However, those industries are the least mentioned as the ones applying the KET technologies, so the rest of the sample is representative for the analysis. Representativeness according to size is given in Table 2, and the sample is representative.

Table 2: Representativeness according to size in terms of the number of employees

	Population	Sample	Z	Representative
> 10 and < 50	1606	19	-1.12	Rep
51 to 250	567	3	-1.36	Rep
> 250 employees	139	13	0.97	Rep

4. RESULTS

In the whole sample, 28% of companies use some key enabling technology, 72% do not use the technology, but out of those who do not use KETs, 24% think or plan to use them. Table 3 presents the used technologies.

Table 3: Used technologies

Technology	Number of companies using
Advanced materials	
Advanced steel (iron) alloy	5
Advanced non-ferrous alloys	5
Super alloys	1
Polymeric composites (polymer-matrix composites)	8
Polymeric composites (metal-matrix composites)	3
Ceramic composites (composites with ceramic matrix)	2
Synthetic non-conductive polymeric materials	4
Conductive polymers	2
Nanofibers (nanotubes, fullerenes)	0
Nanocomposites	1
Nanoceramic	0
Nanopowders	0
Nanocrystals	0
Piezoelectric ceramics	1
Advanced coatings (multifunction, nanostructured, gradient ...)	1
Biomaterials	2
Micro– and nanoelectronics	
Semiconductors in the information and communication technology	5
Semiconductors for the medical industry	0
Nano materials	
Usage in construction (antibacterial coatings, coating against fire, ..)	1
Environment/energy (storage batteries, catalysts, heat exchangers, filters, solar cells, ...)	2
Textiles (fabrics resistant to heat, antibacterial textiles, ...)	3
Chemistry (nanosilica, polymers, ferofluids, carbon nano tubes, artificial silk, nanopigments ...)	1
Automotive industry (fasteners rubber, anti-fogging coatings, anti-reflective displays, ...)	0
Electronics (hard drives with GMR heads, silicone and polymer electronics, phase shifting, ferroelectric and magnetic memory, ...)	2
Optics (ultra precision optics, optical microprocessors, EUV optical lithography, ...)	2
Medicine (marker substances, contrast agents, biocompatible implants, ...)	0
Industrial Biotechnology	
Biopolymers fibers	1
Biodegradable plastics	1
Biofuel	3
Industrial enzymes	2
Antibiotics and vitamins	2
Chemicals (amino acids, organic acids, detergents, cosmetics ...)	2
Photonics	
Consumer electronics (lighting, displays, CD / DVD ...)	8
Conversion of solar energy	0
Optical fiber cables (telecommunications)	7
Optical systems (various scanners, sensors, lasers, ...)	7
Medical diagnosis, contact lenses, microscopes, medical lasers, ...	0
Advanced manufacturing systems	
Production system that produces at a higher speed compared to conventional production	8
Production system that reduces material consumption	8
Production system which increases accuracy	9
Production system that reduces environmental impact	8
Production system that is smaller in size	3

Figures 1 and 2 display the usage of KET technologies by industry and by size.

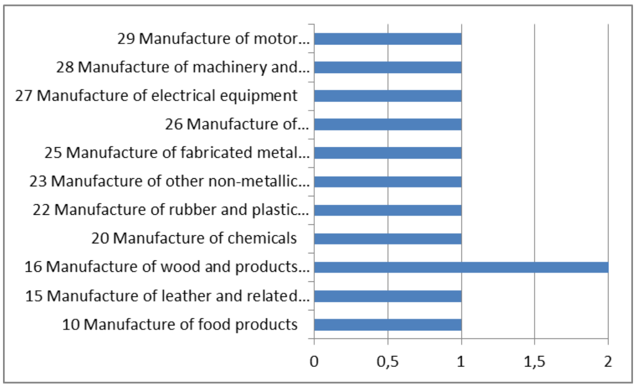

Figure 1. Usage of KET-related technologies by industries

Looking into the industries, it can be seen that in almost all industries that were representative for the sample there is at least one company using KET-related technologies. This proves the general applicability of KET technologies.

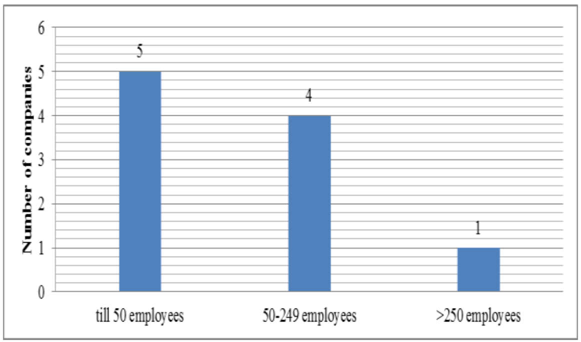

Figure 2. Usage of KET-related technologies by the size of the company

The hypothesis that small companies do not use KET-related technologies seems to be wrong as the majority of KET users fall into small companies. This was further investigated during the workshop and indeed it is usually easier for a small company to acquire the latest technology, which then does not necessities much labor work, and therefore the result is that more micro companies use these latest technologies.

Further in the questionnaire were the questions addressing the barriers of the implementation of KET-related technologies. Table 4 presents the main barriers.

Table 4. Main obstacles in applying KETs

Reasons for not using KET technologies	Number of companies
Lack of financial resources	13
Unknown application potentials	11
Uninformed	11
Lack of knowledge	9
Not applicable for our production	6

The reasons from Table 4 fall into three categories: lack of financial resources, lack of knowledge and not applicable. The workshop had to reveal the problems associated with the two dominant problems, that is, the lack of financial resources and lack of knowledge.

One way to enhance the transfer of technology from research institutions to companies is their cooperation. In the questionnaire there was an open question regarding why companies and research institutions do not cooperate more. The answers fall into these five categories:

- communication problems
- it is unknown to the industry what research institutions explore and vice versa, the research institutions are not aware of the practical problems in the industry
- a lack of workshops between the research and industry in a simple understandable language
- high cost of Croatian research institution’s fees
- corruption in Croatia

Apart from corruption in Croatia, the problems of cooperation are universally the same as in the rest of the world [22], [23].

5. WORKSHOP RESULTS

At the beginning of the survey process all companies (2037) were invited to a free workshop on KETs. The workshop was marketed several times during the conduction and the end of the survey. The workshop consisted of an introductory overview on why KETs are important for Europe and some practical applications of KETs in everyday products. That was followed by the results of a similar survey in Slovenia, and a presentation on how German institutes cooperate with companies on technologies that Germany adopted as strategically important. Finally, the obstacles were addressed.

5.1. Lack of financial resources

A small presentation was done on the subject by giving the examples on how companies from Poland, Slovenia and China surmounted this problem. The point was that companies, in cooperation with research institutions, should apply for EU or government funds. Two problems regarding this came up in the workshop. First, companies already applied in such a way for the funding, but did not obtain it. A careful talk about this proposal revealed that what was too high was a consortium of manufacturing companies and the level of detail about the company that had to be disclosed. It was then suggested that in order to increase the chances of getting funds, companies should cooperate with research institutions or education institutions, and the second point was that the choice of the leading partner that has the know-how of writing a research proposal is extremely important. Another problem that the participants mentioned was that even when it is directed by the CEO to apply for funding, the employees do not get extra time for writing proposals, rather it becomes an after work duty which is certainly not convenient and leads to many errors.

5.2. Lack of knowledge

Companies using KETs or planning to use KETs obtained the knowledge from companies that provide KET technologies. Companies did not do research about the technologies themselves. In fact, the information about KET technologies in Croatia are extremely scarce, unlike in Germany where national chambers and ministries send brochures educating the companies of the potential positive use of technologies. All participating companies revealed an interest in quarterly workshops on a certain technology where they would get the knowledge of potential applications, but where they would also meet each other and discuss how to implement a certain technology and how they solved the obstacles.

5.3. Collaboration with research institutions

There is a substantial problem in cooperation between the companies and research or education institutions. Participants of the workshop indeed said that this was the first workshop in an easily understandable language about advanced technologies. Additionally, it was free. Participants from the Faculty of Mechanical Engineering did in fact confess that they only do commercial cooperation with companies mostly by lending the newest equipment, which they in fact obtained by applying for the national or EU research grants. It seems that the problems with cooperation are truly serious and cannot be easily remediated. Rather, it is necessary to start building trust between the research institutions and companies, in a way that research institutions and education institutions devote some of their time to giving free workshops to the industry in order to build this trust. The leading countries in technology and competitiveness (USA, Japan, China) do in fact conduct more applicative rather than basic research, unlike Europe, where fundamental research is more dominant [1]. It means that the research and higher education institutions in Croatia should start building this relationship for a mutual benefit.

6. CONCLUSION

Even in a small country such as Croatia, research showed that 28% of surveyed companies do use some of the key enabling technologies. Among the dominant reasons for not using the technologies are a lack of financial resources, unknown application potentials and a general lack of knowledge on key enabling technologies. It is advised to companies to use the European structures funds or national funds [24]. However, the communication problems are serious and may be even more serious than in the developed and developing countries. The workshop revealed that companies would in fact truly appreciate quarterly workshops on a certain technology to start building the trust in research and higher education institutions. In this way, the applicative problems would also be discussed, which could enhance the number of applicative research instead of fundamental research. This would enhance the technology transfer and it would help companies to gain more knowledge about the technologies and in that way be better in communicating with the KET providers that approach them.

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