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NEW SUPPLY CHAIN CONCEPTS, FLEXIBILITY AS A KEY PARAMETER OF AGILE SUPPLY CHAINS

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Abstract: Optimization of supply chains results new models, concepts of value chains and new organization and cooperation forms of members. Nowadays growing market globalization, increasing global competition, more and more complex products requires new production technologies, methods and processes. The product life cycle is getting shorter and shorter, the complexity of final products is increasing and new customer demands require efficient operation of supply chains. Usually three new supply chain concepts are used, the lean, the agile and leagile supply chains. Different manufacturing systems are using these chain concepts, Dedicated Manufacturing Lines (DML) are using lean, Flexible Manufacturing Systems (FMS) agile and Reconfigurable Manufacturing Systems (RMS) are using leagile concepts. In this paper we introduce supply chains and the relating manufacturing systems. We also give an overview of flexibility constraints as an important requirement of nowadays manufacturing, applied in agile supply chains.

1 Supply chain, enterprise, virtual enterprise

Generally, supply chain is a network with different elements, like organizations, activities, resources. Stevens [1], [9] gave a more precise definition, the supply chain is a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together in order to fulfill different customer demands. So concluded that supply chain is a cooperation of business partners driven by business requirements and customers. Due to the fast changing customer demands, market environment and globalization, new supply chain models are developed, like lean, agile and leagile supply chains.

Enterprise is a collection of business processes that combined to produce desired results. Business process is a time ordered set of activities that accomplishes a purpose.

Virtual enterprise is a cooperation of enterprises, which enterprises are the members of the supply chain. It is a virtual temporary alliance between the chain members. The enterprises come together to share their skills, resources, and knowledge in order to better respond to business opportunities [2]. Supply chains and a possible virtual enterprise can be seen in Figure 1. Their main aim is to understand the customer demands and fulfill these fast. These virtual organizations are used in more and more industries, e.g. fashion industry, food industry, automotive industry, etc [3], [4].

Gunasekarana at al. [5] defined that virtual enterprises are characterized by several strategic objectives:

- maximizing flexibility and adaptability to environmental changes,
- developing a pool of competencies and resources,
- reaching a critical size to be in accordance with market constraints, and
- optimizing the global supply chain.

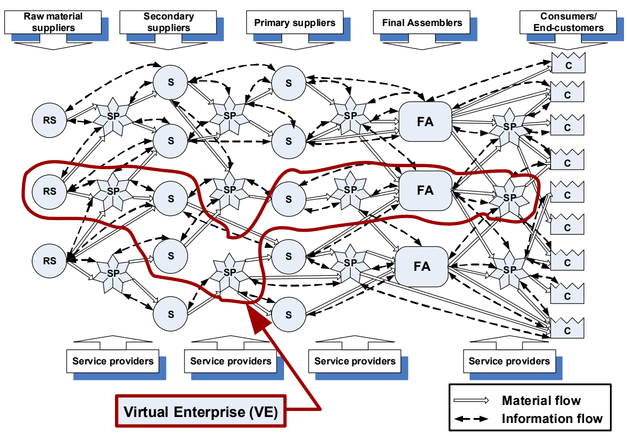

Figure 1 Supply chain networks and a possible virtual enterprise

1.1 Lean Supply Chain

The main goal in a lean organization is to improve the customer value through a perfect value creation process, that has zero waste. It also can be defined to create more from less, eliminate all wastes, and every non-value adding activities in the whole supply chain process at every member of the chain. The possible type of wastes can be divided in three groups:

1. Unobvious waste.
2. Less obvious waste: it occurs as a result of variability sources such as process time, delivery times, yield rates, staffing levels, and demand rates.
3. Obvious waste: it includes inventory, unneeded processes, excessive setup times, unreliable machines and rework.

Lean is capable of eliminate the obvious waste, and reduce the less obvious waste [6]. This strategy is used usually in mass production, in a stabile, controllable and predictable environment, based on long term trading relationships between the chain members. Usually manufacturing goods with longer life cycle (longer than 2 years), where customer demands are well predictable, and the variety of products is low.

1.2 Agile Supply Chain

The purpose of the agile concept is to quick response to the fast changing market demands. This paradigm relates to the relation between companies and markets. Agile supply chain needs to be flexible and can respond to rapidly fluctuating end customer demands and unpredictable market changing.

One of the first agility definitions comes from the Iacocca Institue of Lehigh University in the United States, they said agility is the ability to cope with unexpected challenges, to survive unprecedented threats of business environment. Agility also has the ability to take advantage of changes as opportunities [7]. Another definition for agility: "it is a business-wide capability that embraces organizational structures, information systems, logistics processes and, in particular, mindsets [8]."

Kidd gave probably the most accurate definition, what is agility in a virtual enterprise. In his opinion agile enterprise characterized by a fast moving, adaptable and robust enterprise, in business market. It also means the enterprise is capable of rapid adaptation in response to unexpected and unpredicted changes and events, market opportunities, and customer requirements.

Agile manufacturing based on three different principles [9]:

- innovative management organization,
- highly trained workers,
- flexible high-tech solutions.

Based on Gunasekaran's definition, agile concept is a vision of manufacturing. It is a result of development process and it is evolved from lean concept. We also can say agility is a business-wide capability that embraces organizational structures, information systems, logistics processes. The key characteristic of an agile organization is flexibility, and the origins of agility can be found in flexible manufacturing systems (FMS).

1.3 Leagile Supply Chain

Leagile concept was developed by Naylor [10]. It is a mixture of lean and agile concepts with their advantages. Using lean techniques, like low production costs as possible, and minimal stocks combining these with the flexibility of agile manufacturing. Leagility is typically applied to the production of "custom-assembled" products, where customer demand forecasts are fairly accurate. In leagile concept innovative technology is used to increase the quality of the produced goods, or ensure uniqueness. This strategy provides an opportunity to produce huge variety of goods with higher manufacturing cost.

2 Comparison of lean, agile and leagile supply chain concepts

Leanness should not be confused with agility, Cristopfer and Towill [8] showed it. Hill [11] developed his own concept for "order qualifiers" and "order winner" criteria. Later in literature other authors changed these terms to market qualifiers and market winners as it can be seen in Table 1. These helps us to make decision which strategy has more advantages in our enterprise. There is borderline between lean and agile concepts, and these order qualifiers and order winner criteria helps to understand it. Lean concept is much stronger than the order winner criteria is cost. This means lean concept is very useful when a company would like to manufacture very similar products in a mass production system. In contrast to lean, agile concept is used when service level is the winner criteria.

Table 1 Difference between lean and agile concepts [8]

Market qualifier strategies	Market winner strategies	
1. Quality 2. Cost 3. Lead Time	1. Service Level	Agile supply
1. Quality 2. Lead Time 3. Service Level	1. Cost	Lean supply

The attributes of lean, agile and leagile supply chains are compared to each other in Table 2.

Table 2 Comparison of lean, agile and leagile concepts [12]

Distinguishing attributes	Lean supply chain
Market demand	Predictable
Product variety	Low
Product life cycle	Long
Customer drivers	Cost
Profit margin	Low
Dominant costs	Physical costs
Stock out penalties	Long term contractual
Purchasing policy	Buy goods
Information enrichment	Highly desirable
Forecast mechanism	Algorithmic
Typical produts	Commodities
Lead time compression	Essential
Eliminate muda	Essential
Rapid reconfiguration	Desirable
Robustness	Arbitrary
Quality	Market qualifier
Cost	Market winner
Lead-time	Market qualifier
Service level	Market qualifier

Distinguishing attributes	Agile supply chain
Market demand	Volatile
Product variety	High
Product life cycle	Short
Customer drivers	Lead-time and availability
Profit margin	High
Dominant costs	Marketability costs
Stock out penalties	Immediate and volatile
Purchasing policy	Assign capacity
Information enrichment	Obligatory
Forecast mechanism	Consultative
Typical produts	Fashion goods
Lead time compression	Essential
Eliminate muda	Desirable
Rapid reconfiguration	Essential
Robustness	Essential
Quality	Market qualifier
Cost	Market qualifier
Lead-time	Market qualifier
Service level	Market winner

Distinguishing attributes	Leagile supply chain
Market demand	Volatile and unpredictable
Product variety	Medium
Product life cycle	Short
Customer drivers	Service level
Profit margin	Moderate
Dominant costs	Both
Stock out penalties	No place for stock out
Purchasing policy	Vendor managed inventory
Information enrichment	Essential
Forecast mechanism	Both/either
Typical produts	Product as per customer demand
Lead time compression	Desirable
Eliminate muda	Arbitrary
Rapid reconfiguration	Essential
Robustness	Desirable
Quality	Market qualifier
Cost	Market winner
Lead-time	Market qualifier
Service level	Market winner

3 Relations between supply chain concepts and different manufacturing systems

Due to digitalization and to the spreading digital enterprise technologies engineers has more opportunities to develop new, to improve and optimize existing manufacturing systems in order to meet customer and logistics demands such as shorter lead time, low stock levels. Nowadays companies which still using Dedicated Manufacturing Lines (DML) systems cannot fulfill these demands quickly, and this encouraged them to develop new technologies. As a result of this process, new systems called Flexible Manufacturing System (FMS) and Reconfigurable Manufacturing Systems (RMS) are developed. These new systems can react to disturbances occurred in supply chains much better and more quickly. The new supply chain concepts and the related manufacturing systems can be seen in Table 3.

Table 3 Supply chains and related manufacturing systems

Supply chain concepts	Manufacturing Systems
Lean supply chain	Dedicated Manufacturing Lines
Agile supply chain	Flexible Manufacturing Systems
Leagile supply chain	Reconfigurable Manufacturing Systems

There is strong connection between supply chains and manufacturing systems. Manufacturing systems can be divided into three main categories. The first one is dedicated manufacturing lines (DMLs). These are mostly designed in order to manufacture only a few variables of products with the highest efficiency. This manufacturing type is very useful for mass producting. The second type is flexible manufacturing systems. These systems produce different kind of parts in lower volume, as Huettemann described [13]. Flexible manufacturing system machines are using more variety and complexity of operations in contrary the machines of DML systems has much more simple operations [14]. Both types have their own properties, DML systems are using lean principle, and FMS is closer to agile manufacturing.

Naylor [10] defined leagility and later Purvis [15] showed her own leagility concept as a mixture of lean and agility. Another type of manufacturing systems has defined by Koren and Shpitalni called Reconfigurable Manufacturing System. This system concept is combining the advantages of DML and FMS, like Naylor combined lean and agile supply chain concepts [16][7]. The most important characteristic of RMS is flexibility, but also focus on low stock limits, and short production times.

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4 Flexibility as a key characteristic of flexible manufacturing systems and agile suppl chains

It is important to distinguish different types of supply chain concepts, because all of them has different type of flexibilities, and as a result of this there is a huge difference what flexibility means in lean, agile, and leagile supply chains. Generally, flexibility can be defined as the sensitivity of the manufacturing system to changes for example product variety and production volume changes.

This sensitivity means convertibility and scalability too. It is a metric that can be applied to different types of systems, and focuses on how responsive a system to changes. If a system has a higher level of flexibility, than it can react on much easier to surroundings. In agile supply chains flexibility is one of the most important property, because the systems which are using this concept has to react on the most quickly to customer requirements. The name "agile" is comes from this basic principle and it is a base property of agile supply chain networks, where the members of the chain are cooperating in form of virtual enterprise. The flexibility of an agile supply chain comes from the flexibilities of the chain members, companies.

In literature there is a lot of interpretation of different flexibilities. Vokurka and O'Leary-Kelly defined 15 dimensions of manufacturing flexibility parameters [20]. Oke defined two main categories of flexibility: internal and external flexibility. Internal flexibility describes the system behavior, while external flexibilities effects to the performance of the company. Machine and process flexibility is about how easily we can modify the production, and how to create the same parts in different ways. Operation flexibility is the ability to sequence production in certain ways. Capacity is about how fast we can react when the production capacity is changing. Routing flexibility is an ability to carry on production even we have different stochastic breakdowns in our system [17]. Malhotra refers internal flexibilities as a scope of flexibility which can be achieved without incurring performance penalties [18]. Some other authors defined a lot different flexibilities, for example Naim analyzed transportation flexibility, Zhang examined logistics flexibility as an important factor of customer satisfaction [19].

Purvis summarized in a state of the art article the categories and most cited flexibility parameters, and also suggested a new way to categorize them. She recommended vendor and sourcing flexibility. Vendor flexibility is similar to internal flexibility like Naim suggested, but also includes warehousing and transportation flexibility. Sourcing flexibility referred as an external property and it includes supply network flexibility. In the article a framework has suggested for supply network flexibility [15]. The categorization of most cited flexibilities are in Table 4.

Table 4 Categorization of flexibility parameters based on literature

Oke [21]	Naim [10]		Purvis [15]	
	External	Internal	Source	Vendor
Volume Production Product Delivery	New product Mix Volume Delivery Access	Machine Process Operation Capacity Routing	New product Mix Volume Delivery Organizational	Manufacturing (machine, process, operation, capacity, routing) Warehouse Transportation

Table 5 Our suggested flexibility parameters

Flexibility parameters	
Internal flexibilities	*External flexibilities*
Machine Process Capacity (Re)Routing Operation Material handling Automation	Product Volume Delivery Mix Informatics technology Network relationship

There are a lot of other flexibility categories in literature, almost every author has defined his own ideas for flexibility, but many of them is near the same. We also suggested our categorization based on the earlier presented authors work.

In our categorization we use the terms of internal and external flexibilities, like some other authors suggested it. We complement Naim's internal flexibility parameters with material handling and automation flexibility parameters. The used material handling system which involves such activities as moving, handling, storing gives a very important metric for the manufacturing system flexibility. Automation flexibility is the ability for a robot or system to be quickly and easily re-tasked to change product design for both low and high mix manufacturing. We also add a few new parameters to external flexibility category, like information technology and relationship flexibility parameters. Relationship is willingness to cooperate in order to design and manufacture completely new products. Informatics technology (IT) flexibility is gives us an overview of smooth in competence sharing and its data processing.

Summary

In this paper we gave an overview of the newest supply chain concepts and the connecting manufacturing systems. Agile supply chain as a new supply chain concept which is a result of nowadays globalization and fast changing customer market. Manufacturing companies has to adopt this concept in order to remain competitive, and to react quickly to customer requirements. Flexibility is a base property of these systems. We introduced the definition and different flexibility parameters based on the literature, and we suggested a new categorization of flexibility parameters and new flexibility constraints. Our suggested flexibilites can be seen in Table 5.

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References

[1] STEVENS, G. C.: Integrating the Supply Chain, *International Journal of Physical Distribution & Materials Management*, Volume 19, Issue 8, pp.: 3-8, 1989.
[2] CAMARINHA-MATOS, L. M.: Execution system for distributed business processes in a virtual enterprise, *Future Generation Computer Systems,* Volume 17, pp. 1009-1021, 2001.
[3] GUBÁN, M., GUBÁN, M., KEREPESZKI, I.: *Mathematical model and solution method of ordering controlled virtual assembly plants and service centres,* 3rd Central European Conference in Regional Science, Košice, Slovakia, Technical University of Kosice, Conference proceeding, pp. 316-325., 2009.
[4] GUBÁN, M.: *Non-linear programming model and solution method of ordering controlled virtual assembly plants,* Logistics - The Eurasian Bridge: Materials of V. International scientifically-practical conference, Krasnoyarsk, Russia, Krasnoyarsk State Agricultural University, Conference proceeding, pp. 49-58., 2011.
[5] GUNASEKARAN, A., LAIB, K., EDWIN CHENG, T.C.: Responsive supply chain: A competitive strategy in a networked economy, Omega, Volume 36, Iss 4, pp.: 549-564, 2008.
[6] GUNASEKARAN, A.: Agile manufacturing: a framework for research and development, *International of Production Economics*, Vol. 62, pp. 87-105, 1999.
[7] IACOCCA INSTITUTE, *21.st Century Manufacturing Enterprise Strategy*, Lehigh University, Bethlehem, PA, 1991.
[8] CHRISTOPHER, M., TOWILL, D.R.: Supply chain migration from lead and functional to agile and customized, *Supply Chain Management: An International Journal,* Vol. 5, Number 4, pp. 206-213, 2000.
[9] KIDD, P.T.: *Agile Manufacturing: Forging New Frontiers*, Addison-Wesley, Reading, MA, 1994.
[10] NAYLOR, J.B, NAIM, M.M, BERRY, D.: Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain, *International Journal Production Economics,* Vol. 62, No. (1/2), pp. 107–118, 1999.
[11] HILL, T., *Manufacturing Strategy: Text and Cases,* 2nd ed., Macmillan, London, 1993.
[12] AGARWAL, A.; SHANKAR, R.; TIWARI M.K.: Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach, *European Journal of Operational Research - Production, Manufacturing and Logistics*, 173, pp. 211–225., 2006.
[13] HUETTEMAN, G., GAFFRY, C., SCHMITT, R. H.: *Adaptation of Reconfigurable Manufacturing Systems for Industrial Assambly – Review of Flexibility Paradigms*, Concepts, and Outlook – Procedia CIRP 52, pp. 112-117, 2016.
[14] KOSTAL, P., VELISEK, K.: Flexible manufacturing system, World Academy of Science, *Engineering and Technology,* Vol. 77, pp. 825-829, 2011.
[15] PURVIS, L., GOSLING, J., NAIM, M.M.: The development of a lean, agile and leagile supply chain taxonomy based on differing types of flexibility, *International Journal of Production Economics,* Volume 151, pp. 100-111, 2014.
[16] KOREN, Y., SHPITALNI, M.: Design of reconfigurable manufacturing systems, *Journal of Manufacturing Systems*, Vol. 29, No. 4, pp. 130–141, 2010.
[17] NAIM, M., POTTER, A. T., MASON, R.J., BATEMAN, N.: The role of transport flexibility in logistics provision, *The International Journal of Logistics Management,* Vol. 17, Issue 3, pp. 297-311, 2012.
[18] MALHOTRA M. K., MACKELPRANG A .W.: Are internal manufacturing and external supply chain flexibilities complementary flexibilities?, *Journal of Operations Management 30*, pp. 180-200, 2012.
[19] ZHANG, Q., MARK, A. JEEN-SU LIM, V.: Logistics flexibility and its impact on customer satisfaction, *The International Journal of Logistics Management,* Vol. 16, Issue 1, pp. 71 – 95, 2005.
[20] VOKURKA, O.J., O'LEARY-KELLY, S.W.: A review of empirical research on manufacturing flexibility, *Journal of Operation Management 18,* pp. 485-501, 2000.
[21] OKE, A.: A framework for analysing manufacturing flexibility, *International Journal of Operations & Production Management,* Vol. 25, Issue 10, pp. 973–996, 2005.

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MATERIAL AND ECONOMICAL ASPECT OF SOME PLASTICS USING IN AUTOMOTIVE INDUSTRY

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Keywords: plastics, composite, automotive, material, industry
Abstract: Plastics, plastics composites are used for lighter construction vehicles, where they provide support, the corresponding for these progressive approaches constitute the main article for in design-oriented styling, interior car design support according to detailed customer requirements. Using plastics materials in th automotive industry is focused on active and passive safety of vehicles and passangers of course, optimizing aerodynamics, noise reduction, ecology and recycling.

1 Introduction

According to study of "Automotive Plastics Market" [1] It has been estimated that every 10% reduction in vehicle weight results in a decrease fuel economy by 5% to 7%. Currently, the condition to respect the economical and environmental measures in automobile [1].

Among the important advantages of high performance plastics used in vehicles include:

- Minimum corrosion, thereby extending the life of the vehicle
- Significant design freedom in design, allowing for an increase in creativity and innovation
- Flexibility to integrate components
- Safety, comfort and economic side.
- Recycling and recovery of plastic materials [2].

In general, the global market in terms of the use of plastics in the automotive industry increased in 2015 in the 8 *kt*. This means that the application possibilities of plastics in the automotive industry are currently focused on track to use. In addition to the aforementioned advantages of using, there is a kind of "superiority" of plastic material, into the actual design. Plastics are characterized by improved weathering resistance and versatility in applications.

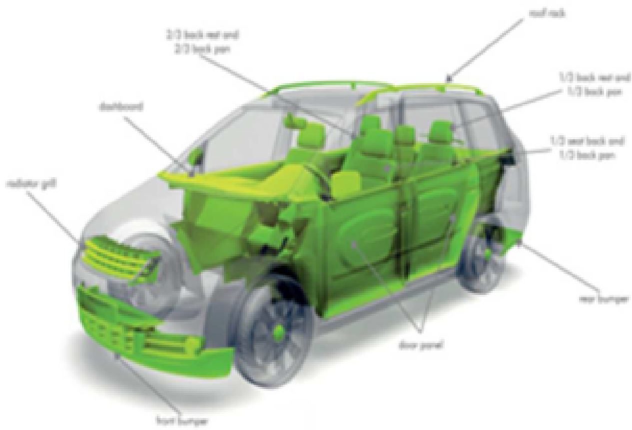

Figure 1 Plastics in the car [3]

2 Plastics in the automotive industry

European Commission adopted already in 2012, strict government regulations on reducing emissions of vehicles [2], [4]. This forces manufacturers to transition the use of lightweight plastics to replace metals such as aluminum and steel (Figure 1), (Table 1). The average car is made of plastic in the range of 5.8% to 10% of its total weight, depending upon the performance requirements and fuel efficiency standards, whether the consumption of vehicle components. In general, the one car account for ca. 105 kg of plastic. Next table presented materials used in the car industry.

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Table 1 Plastics in the car [3]

The materials used in the car industry	
Steel	41%
Non-alloy steel	18%
Aluminium	8%
Iron	6,4%
Zinc,copper, magnesium	2%
Rubber	5,6%
Plastics	9,3%
Other materials	9,7%

A high percentage of the plastic material used (or components) is expected in the future due to the growing demand from consumers, where the important role of weight loss, low power consumption and high performance vehicles on the contrary [4], [5].

In addition to reducing the overall weight of the car, the materials of plastov- of plastic composites used to improve aesthetics, reduce noise and vibration insulation car. The most used types of plastic in the automotive industry make up approximately 66% of all high strength plastic. The characteristics of the most widely used plastic in the automotive industry [2], [4]:

- Polypropylene(PP)

Polypropylene is a thermoplastic polymer used in a wide application range. Saturated addition polymer is made from monomers of propylene, it is resistant to most chemical solvents, and acids. Usage: car bumpers, chemical tanks, cable insulation, gas tanks, carpets.

- Polyurethane(PU)

Polyurethane elastomeric material is of exceptional physical properties, including toughness, flexibility and resistance to abrasion and temperature. Polyurethane has a wide range of hardness (from soft rubbers to the hardness of bowling balls). Polyurethane is characterized by extremely high durability, high lifting capacity and excellent resistance to weathering, ozone, UV, resistance to oil, gasoline and most solvents. Application: flexible foam within the application to the seats, foam insulation panels, automotive hinges, cases, pillows, pads electric cables and hard plastic parts.

- Poly (vinyl) chloride (PVC)

PVC has good flexibility, is flame retardant and has good thermal stability, high gloss. Polyvinyl chloride materials may be extruded, injection molded, pressed and thus allow forming a plethora of products, whether rigid or flexible, depending on the amount and type of plasticizer used. Material application in automotive toolbars, sheathing of electric cables, pipes, doors.

- Acrylonitrilbutadienstyrene (ABS)

Copolymer is prepared by polymerization of styrene and acrylonitrile in the presence of polybutadiene. Styrene gives the plastic a shiny impervious surface. ABS is material with improve impact resistance, toughness and heat resistance. Application: construction of a car dashboard trims.

- Polyamide (PA, Nylon 6/6, Nylon 6)

Nylon 6/6 is a general purpose nylon, has good mechanical properties and wear resistance. It is often used after the desired low cost, high mechanical strength. Is rigid and stable material. Nylon is water and the high absorbency increased humidity. Applications: gears, cams, bearings, paints weatherproof.

- Polystyrene (PS)

It shows excellent chemical resistance and electrical resistance. Processing technology is simple. Materials made from PS have poor UV resistance. Use: The device covers, buttons, the display on the dashboard.

- Polyethylene (PE)

Polyethylene has high impact strength, low density, and has good toughness. It can be used in a variety of thermoplastic processing techniques, and particularly is useful where the material is desired moisture resistance but a low cost. Application as car body (using glass fiber), electrical insulation.

- Polyoxymethylene (POM)

POM has excellent rigidity, strength and yield stress. These characteristics are constant at low temperatures. POM is also highly resistant to chemical solvents and fuel. Application: interior and exterior moldings, fuel systems.

- Polycarbonate (PC)

Amorphous polycarbonate polymer is characterized by a unique combination of stiffness, hardness and toughness. It exhibits excellent resistance to weathering, creep. It has excellent optical, electrical and thermal properties. Due to its extreme severity of the accident, the material is suitable for automotive bumpers. Using as bumpers, headlights, indoor luminaires

- Polymethylmethacrylate (PMMA)

It is a transparent thermoplastic, often used as an alternative to glass. In view of the price it is less expensive than PC, but is also susceptible to scratching and breakage. Application: windows, display screens [5].

- Polybutylene terephthalate (PBT)

Thermoplastic PBT is used as insulating material. It is highly chemical and heat resistant. Applications: door handles, bumpers, parts carburetor.

- Polyethylene terephthalate (PET)

PET is mostly used for the production of wiper arms and gearboxes, engine cover headlight brackets, connector covers.

- Acrylonitrile styrene acrylate (ASA)

As with ABS and ASA it has great strength and rigidity, good chemical resistance and thermal stability, exceptional resistance to weathering, aging and yellowing and high gloss. Application: profiles, interior and exterior parts obloženie- bar.

- Polyvinyl butyral (PVB)

Manufacture and usability of this type of thermoplastic has been described in previous chapters. It characterized by use for the production of PVB films. Further, the PVB resin used in the production of coatings, structural adhesives, color dry toners, and as a binder in the manufacture of composite materials. PVB film has a number of excellent characteristics, namely high tensile strength, impact resistance, transparency and flexibility which are especially useful in the manufacture of safety glass windscreen [5], [6].

3 Reasons for the use of plastics in the automotive industry

Modern science and research worldwide is investing in financial resources in the development and production of new materials applicable law in the automotive industry. By continuously improving and developing new technologies and materials are being car has become the market leader. Automotive industry, it is not just a "production car" is a comprehensive service which affects the engineering, electrical and chemical industries, respectively industry [7]. It is therefore necessary to look at it from several sectors that one complements the other and each other is eliminated [4]. The dynamic development, constantly new requirements from customers and especially the ability to remain on the market, a set of requirements and capabilities of each party. This means constant interaction "research (development)-manufacture-customer". Recently, the requirements of the automotive industry have changed significantly.

The most important factors that influence the development and design of the car include:

- Costs
- The final consumption
- Recyclability and
- Emissions [4], [5].

Just last two factors were 15 years ago in the background. Impact of enlargement European Union's borders be done through strengthening the standards relating to the production of useful materials, their environmental impact and overall impact on the environment [5].

Present in the automobile industry clear, largely the metal parts of the car are replaced by plastic. Research and development of advanced materials, and invest in improving existing materials (and thus increasing the competitiveness of the market) is crucial for the automotive industry, in terms of:

- Design,
- Performance,
- Fuel,
- Corrosion resistance,
- Low operating costs,
- Tightening environmental standards,
- Crash safety (people and cars) and so on [4].

Just above mentioned factors directly and indirectly forcing car manufacturers to use new, advanced materials (Table 2). They are characterized by higher strength relative to their weight, and in particular by better combining of their mechanical properties.

Table 2 The most commonly used types of plastics

Plastics in the car	
PP	32%
ABS	31%
PA6/PA 6.6	31%
PU	17%
PVC	16%
PBT	5%
PVB	2%
PET	1%

Conclusions

Application of plastics and composite materials based on plastics are nowadays of great importance in terms of usability, refund the original materials, reducing the overall weight of the car and especially prices.

References

[1] KNAPČÍKOVÁ, L., HERZOG, M., ORAVEC, P.: Material characterization of composite materials from used tires, *Výrobné inžinierstvo*. Vol. 2010, No. 4, p. 31-34, 2010. <www.tuke.sk/fvtpo/casopis>.
[2] KNAPČÍKOVÁ, L.: Skúmanie reologických vlastností kompozitov na báze textílií z opotrebovaných pneumatík, *Plasty a kaučuk*, Vol. XLVIII., No. 1-2(2011), p. 4-5, 2011. (Original in Slovak)
[3] Automotive plastics, [Online], Available: https://plastics-car.com [30.12.2016].
[4] The use of risk assessment in environmental management, [Online], Available: http://www.eea.europa.eu/publications/GH-07-97-595-EN-C2/chapter2h.html [30.11.2016].
[5] KNAPČÍKOVÁ, L, ORAVEC, P.: Characterization of fabric component from used tires with differential scanning calorimetry, MendelNet 2010, proccedings of International Ph.D. Students Conference, Brno, November 24th, p. 541-545, 2010.
[6] Progresívne vyvíjané polymérne kompozity v automotive, [Online], Available: http://www.zapsr.sk/progresivne-vyvijane-polymerne-kompozity-v-automotive/ [01.12.2016]. (Original in Slovak)

[7] BALOG, M. et al.: Automation monitoring of railway transit by using RFID technology, *Acta Tecnología,* Vol.1, No.1, p.9-12, 2015.

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URBAN WIND TURBINES AND THE POSSIBILITY OF THEIR USE IN SLOVAKIA

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Abstract: Small wind turbines are specially designed for the built environment and can be placed on buildings, embedded in buildings or freestanding on the ground next to buildings. This means that the turbine is designed for the wind in the built environment and withstands the impact of wind and turbulence and that the shape and size of the turbines have been designed to meet the visual conditions of surrounding buildings with the environment in mind. Its purpose is to generate clean emission-free energy for homes, offices, schools, and the like. Thanks to this simple and increasingly popular technology, turbine owners can produce their energy and save not only money but also the environment.

1 Introduction

Small wind turbines are available on the world market in all sorts of concepts, performances, and dimensions. The number of installed small wind devices in the country depends not only on conditions such as relief or the actual wind conditions. But also the policy of the state regarding electricity buyout, public awareness, subsidies during the construction, as well as market and technical assistance and the availability of such equipment and spare parts. Globally, growth in sales of small wind devices is annually increasing. In 2013 was recorded 870,000 installed small wind devices. A global leader is China, which has 625,000 installed units. By a significant gap followed by the US and European countries, led by Britain. The total installed capacity of small wind devices in 2014 reached 730 MW, which compared to 2013 represents an increase of 10.9%.

2 Urban wind turbines

With advances in the technologies of wind turbines, it is possible to use small and micro wind turbines to overcome the unfavorable state of the wind in built-up areas. The emergence of urban wind turbines is given by new technologies and advances in the construction of turbines, plus favorable financial incentives offered by the government, given the ever-increasing energy prices. There is also growing public interest in wind turbines, despite the fact that the public is not sufficiently familiar with this issue [1]. Experts also add that the emergence of urban wind turbines is necessary due to the shift in the approach of centralized production of energy to heat and power generation directly at the place of consumption [3]. But they also point out that the use of known technologies in wind turbines, in the end, might not lead to full exploitation of the potential of turbines. It is, therefore, need for more detailed research and development of new typologies of HAWT – horizontal axis wind turbine and VAWT – vertical axis wind turbine designs that will implement more efficient generators able to cope with the characteristics of the wind in urban areas [4].

Urban wind turbines vary from large wind turbines in many ways. From the perspective of the blade design, small wind turbines require different aerodynamic profile than large wind turbines due to the differences in peripheral speed in proportion to the wind speed. Blades of large wind turbines are more advanced in terms of aerodynamic design than small wind turbines, which are mostly affected by a coefficient of performance of wind turbine. The peripheral speed of a small wind turbine has a direct impact on the transmission system and energy production, and therefore it requires a gearbox. Directly driven systems are more reliable and require less maintenance. Also, the energy of small wind turbines and systems regulating speed are different from large wind turbines, using mechanically controlled systems of slope and deflection, which are different from large wind turbines with an electronic control system. Besides, small wind turbine towers are relatively high, as they need to achieve unimpeded flow of the wind over the windward side of the obstacles.

Urban wind turbines will always be at a disadvantage with the installation in unsuitable places, compared to large wind turbines, due to lower heights in densely populated urban areas. It is also not clear whether urban wind turbines might be standardized in built-up areas due to variable wind direction. Wind flow in this low altitude is influenced by local conditions such as turbulence intensity. Therefore, there are more suitable locations for the progress of the development of urban wind turbines in rural areas and coastal areas - where the sea breeze is present, and suburban areas - where there are fewer barriers to the flow [1].

There are a number of technical issues that need to be addressed in the development of wind turbine systems for built-up areas, which are [4]

1) System type - static, integrated in a building / facility, deflection system, with / without convector and / or diffuser,
2) System attributes - self-triggering, safe, low noise, weak vibration, durable construction, minimal maintenance, lightweight, high performance,
3) Placement - aesthetics, strength of building / infrastructure, electromagnetic interference of existing power facilities, space for other equipment such as monitoring system.

Another aspect is the difficulty of obtaining small wind turbines compared with large ones. Old wind turbines with low capacity can be redesigned and used in the built environment, but in order to maximize energy production from integrated wind turbine in the built environment the following points should be taken into account:

- turbines should preferably be placed on large buildings with extensive roof,
- determine what type and model of turbines are best to use for the selected building and site,
- deploy more turbines on the same site, if possible,
- examine whether the building and its surroundings are suitable for the placement of urban wind turbines,
- acquire the consent for the placement of turbines in the area,
- determine the visual impact on the surroundings - the movement of the blades can produce a visual distortion in the area,
- concentration of turbines placement in certain areas,
- ensure that the turbines are marked in spatial development plans and that this development is respected by all interested parties,
- devote sufficient attention to the aesthetic aspect of integration - the turbines need to be well visually integrated into the building or site.

Regarding the integration of wind turbines within the built environment, there are four main types of integration. Wind turbines integrated within the built environment are classified based on their position in relation to buildings [5]. The main objective is to capture fast winds at low turbulence of flow. And therefore may be urban wind turbines either:

- freestanding on a very high base in the built environment (wind turbines near buildings),
- mounted on the surface of buildings, such as on roofs (building mounted wind turbines),
- fully integrated into the building,
- within the pipes in the building.

2.1 Buildings integrated wind turbines – BIWT

Dutton [2], described wind turbines near buildings as freestanding wind turbines, which are able to work near buildings and benefit from an enhanced flow of wind caused by surrounding buildings. They can be added to existing urban areas or incorporated in its entirety into the design of new built-up areas where the whole project is tailored to their placement. Although wind turbines near buildings can provide more energy than wind turbines mounted on buildings, the price per kilowatt is usually quite high (compared with medium / large wind turbines) due to the need to cover the costs for the foundations of the turbine, tower, and wiring.

An example of this type is small freestanding turbine in Mile and Ecology Centre in London and the wind turbine at the BP station, Wandsworth, also in London, which are 6kW turbines with a blades diameter of 5.5 meters. Another example of this type is the installation of three 15kW wind turbines within the project ZEBRA (Zero Emission Building Renewing Alnwick), where the estimated power is 60,000 kWh per year.

According to the report WINEUR [12], this type of integration in between the built environment is usually being realized in the open spaces and areas of the built environment such as school playgrounds and parks.

2.2 Building mounted wind turbines – BMWT

According to the Royal Institute of British Architects (RIBA), wind turbines mounted on buildings are gaining the most public attention. However, one of the main obstacles, associated with this type is obtaining building permits, but there are a couple of examples of permitted wind turbines mounted on buildings. These devices are more likely to contribute to the supply of electricity within the built environment. Wind turbines are mounted on buildings as physically connected to buildings, where the building plays the role of the vertical pillar for the placement of the wind turbines for the use of required wind flow [2].

Given that the built environment is complex, the urban context could have a significant impact on the flow on the tops of roofs and most likely will be very dynamic, turbulent and include a vertical component. Even at the same roof, the conditions can vary dramatically from one place to another.

According to the project WINEUR [12], the most influencing parameter of wind flow over the roof, is a shape of the roof. Experts also pointed out the importance of the impact of roof shape on the local wind flow. They also mentioned the need to investigate the influence of different shapes of roofs on wind speed and turbulence intensity and how it would be possible to increase the efficiency of energy production from wind turbines placed on buildings. In addition to selecting the optimal place for attachment, a building should be suitable for the placement of wind turbines and should also provide a reduction in vibration and noise [2].

Projects, where the existing buildings were fitted with urban wind turbines, are not always feasible or returnable, but if the design of the building was counting with the possible implementation of wind turbines from the beginning, the results might be better. Concerns about noise, vibration and energy yield can be eliminated, if there is properly conducted evaluation of the wind and application of the correct wind turbine at optimum mounting location. It is said that the wind turbine with a vertical axis of rotation, type Triple-Helix Quietrevolution (QR) (Figure 1), is ideal for urban environments. It is rated at 6 kW, produces 10,000 kWh/year at average wind speeds, it is free standing at approximate height of 14 meters with a span of 3 meters. If it is placed on a building, sufficient height for mounting is 8 meters. Moreover, it is profitable, which makes it attractive for business and building developers.

Figure 1 Wind turbine type Triple-Helix Quietrevolution [10]

In the future it will be likely to see the combined systems of wind turbines and photovoltaic modules fully integrated into the design of the roof. For the conceptual design of the wind turbine mounted on a building, the turbine should have flexible construction design to be easily anchored on a top of the roof or an edge of the building. Therefore, they developed the concept of Darrieus VAWT called Crossflex (Figure 2), which has a flexible system of blades, uses light frame system, which extends the airflow and improves visual integration into buildings. It also has a modular design thanks to which it can be placed on the corners of buildings for generating useful energy level.

Figure 2 Crossflex concept and its mounting [9]

Even though is a placement of each wind turbine specific, there are a few basic procedures to be followed:

- for mounting HAWT on flat roofs, the turbine should be placed near the center of the roof at 35-50% of the height of the building,
- if you cannot place the turbine sufficiently high with relation to the spatial plan, it is preferable to use a VAWT, which can also withstand a high level of turbulence intensity,
- the building, on which the wind turbine is integrated should be higher than the surrounding buildings by at least 30-50% of the height of surrounding buildings,
- full assessment of the wind should be done with due regard to the wind direction and its effect on the orientation of the building,
- the minimum wind speed at the site should be more than 5 m/s and turbulence intensity less than 10%,
- appropriate supporting structure and crane access are also important,
- measures must be taken to ensure sufficient strength of the building structure, which is not as easily reachable in renovated buildings.

2.3 Building augmented wind turbines – BAWT

Wind turbines fully integrated into buildings are those wind turbines capable of producing concentrated energy from aerodynamically shaped buildings. In this case of the integration of wind turbine is the shape of the building used to direct the wind directly into the turbine. The shape of the building serves as a support for integrated wind turbines and as a wind accumulation place. Here is the essential role of the architect in the design of the building, which must be based on aspects relating to aerodynamics. Successful installation of BAWT requires a comprehensive knowledge of aerodynamics of buildings, wind energy, wind energy transformations and assessment of effective costs. The construction of the building may require some adjustments based on the assessment of the wind flow tests in the wind tunnel and CFD simulations. There is a growing interest among architects to integrate wind turbines into their projects and buildings forming into the shape of a funnel. Number of new projects that were based on the principle of aerodynamic buildings to enhance the performance of integrated wind turbines. For example, Bahrain World Trade Centre, Pearl River Tower in China, Strata SE1 in London - all with fully integrated wind turbines in the building.

Bahrain World Trade Centre is designed to collect and compress the wind flow between the two towers, where is the wind turbine with a horizontal axis of rotation placed (Figure 3). Narrowing of the Bahrain World Trade Centre, results in increased wind speed at the location of the turbine up to 30%, resulting in the supply of electricity from turbines in the range of 11-15% of the needs of the building [6]. The same effect of narrowing is implemented on Pearl River Tower, where the building has four large openings, approximately 3 x 4 meters wide. The facade is shaped so as to reduce the forces of resistance and optimize the rate at which wind flows through these openings. These openings act as pressure valves for the building**.**

Figure 3 Bahrain World Trade Centre [6]

Altechnica of Milton Keynes patented the concept, that demonstrates how can be the implemented shape of the roof for the placement of wind turbines.

The system is designed for installation on the crest of the roof or on the top of curved part of the roof. The rotors are incorporated in the structure resembling a cage which are covered with the profile. This profile can be equipped with photovoltaic cells, where the rotors are placed on the top of the curved roof. This effect should lead to concentration of wind in a manner similar to flow around the car hood. The advantage of this system is that it does not interfere with the visual observation for the observer and appears as an integrated part of the building. Also, the system is suitable for installation on existing buildings, with appropriate wind.

Concepts integrating large wind turbines with a vertical axis of rotation in aerodynamically shaped buildings are still under development and appear only in the thoughts of designers and proposals of futuristic buildings. However, buildings like Bahrain World Trade Centre or Pearl River Tower are indeed built, but it is very difficult to acquire the information, which show the performance of the integrated wind turbines in detail, so that we can assess their effectiveness. So far it is impossible to assume that projects such as these will become common in the built environment, given the wind turbines, which are not always visually appropriate. For this reason, the successful design of wind turbines must be built to bring the value for the building itself.

2.4 Diffuser augmented wind turbines – DAWT

Another group of turbines are diffuser-augmented wind turbines, which are covered to increase the concentration of wind (Figure 4). According to [3], unlike conventional wind turbines, DAWT were originally developed for integration into the built environment. The main advantage of DAWT is mainly that they are mostly HAWT and blades are fully enclosed in a casing. Casing is designed for horizontal flow management, where the pressure difference between inlet and outlet of the unit is used to drive the turbine. A form of closure, input, output and installation of spoilers play an important role in obtaining energy from installed wind turbine installed.

During the development, since '70s turbine blades were placed inside the housing profile and prototypes were developed at the University of Rijeka, in Croatia, where the stated yield of such an arrangement of the turbine is increased by 60% as compared to freestanding wind turbines. This is attributed to accelerating effect of the profile that allows the turbine to operate at lower wind speeds, as it collects more wind from different sides and leads it directly to the turbine blades.

Figure 4 Example of the diffuser-augmented wind turbine [6]

However, at high wind speeds there is a risk of excessive stress of the blades, which was resolved by introducing hydraulically controlled openings for discharging air from the turbine housing, which is activated when the pressure in the housing is too high. The main problem remains in the high initial cost of the equipment, due to the use of special material for the manufacture of housing, but it might remain ignored in the long run, considering the energy yield.

The use of cover for the blades has several advantages [3]:

• improved security in the event of failure or loose blade,

• greater energy yield than with conventional wind turbines due to higher pressure differences,

• integrates easily into architectural design,

• visually less intrusive.

On the other hand, it should be noted that if the wind speed exceeds 16 m/s, the effect of the shaft will not be as significant. It is therefore necessary to consider economic factors, before it is decided to use diffuser-augmented wind the turbines, since they are usually more expensive than conventional wind turbines.

3 The legislation of using small wind devices in Slovakia

Among the equipment for the production of electricity through wind power as a renewable energy source, belong undoubtedly small wind installations. According to the installed capacity, small wind installations are considered as those with power up to 20 kW. On the other hand, the law on the promotion of RES speaks about small energy sources as the equipment for the production of electricity from renewable energy sources with a total installed capacity of 10 kW, while the producers of electricity from small power source are provided with a special preferential privileges regarding the connection of the equipment to the distribution network.

With regard to the placement of small wind installations in built-up areas, it must satisfy a number of legal conditions. First of all, the size of a small wind devices. Small wind plant shall be regarded within the meaning of the Constitution § 139b point c) of Act no. 50/1976 Coll. on Territorial Planning and Building Code (Building Act) as a simple structure, if its built-up area does not exceed 300 m2 and 15 m in height. In this case there is a simplified authorization procedure for placement of small wind devices. A simplified method for authorizing construction means that the construction office will decide on the location of the building (by the decision on the location of the building is the building land determined, the building is placed on it, determining of the conditions for the building placement, determining the requirements for the contents of project documentation and the period of validity of the decision), in this decision it can determine that for realization of the construction, the notification for construction office will suffice. The second variant is a situation, where the conditions for placing are clear, given the conditions in the area, the construction office connects area management on building placement with the building proceedings and issues a decision on the authorization of construction (building permit).

If the wind device exceeds the above-described dimensions, the building permits is required for the construction. Thereafter, a valid certificate of practical completion leads to permanent use authorization of the device, and thus to its entry into service.

Of course, issuance of a decision on the location of the construction as well as subsequent building permit or construction notification is preceded by the fulfilment of a number of requirements that are defined by the Building Act, such as requirements for the protection of nature and landscape and the care of the environment, to ensure compliance of urban solution and architectural design of the building with the surrounding environment and the like, and submission of project documentation.

The most important prerequisite for granting a building permit or construction notification - for a small wind device is the assessment process of the effects of construction on the environment.

Since the law on the assessment of environmental impacts does not distinguish wind devices - power plants according to their performance, the impact assessment applies on all wind devices, which represents a substantial administrative and financial burden for small wind devices. All the above conditions apply to small wind devices that may be located, for example in the garden of family house in built-up areas. There is almost no legislative regulation, regarding the placement of small wind installations on residential buildings.

In every apartment building are common areas of the building. Installation of a small source could cover the annual consumption of electricity consumed in the common areas (lighting, door opener, small circulation pumps and partially lift consumption) using the generated electricity from small wind devices directly, or in combination with energy storage. It would also to ensure emergency lighting of staircases and other common areas (requirement STN 1838, 2001) during a power outage from distribution network, thus increasing the safety of the occupants of the house. It is not necessary to be connected to the distribution system for this type of power supply.

Conclusion

Summarizing the above mentioned it could be concluded that the installation of small wind installations in built-up areas in Slovakia represents a substantial administrative and financial burden that is more or less insurmountable. In other words, there is an absence of legislation related to their installation in built-up areas.

References

[1] BAHAJ, A.S., MYERS, L., JAMES, P.A.B.: Urban energy generation: influence of micro-wind turbine

output on electricity consumption in buildings. *Energy and buildings,* Vol. 39, No.2, pp. 154-165, 2007.

[2] DUTTON, A.G., HALLIDAY, J.A., BLANCH, M.J.: The Feasibility of Building-Mounted/Integrated Wind Turbines (BIWTs): Achieving their potential for carbon emission reductions. *Final Report of Carbon Trust Contract*, 2002.

[3] GRANT, A.D., KELLY, N.J.:A ducted wind turbine simulation model for building simulation, *Building Services Engineering Research and Technology*, Vol. 25, No. 4, pp. 339-349, 2004.

[4] BOOKER, J., MELLOR, P., WROBEL, R., DRURY, D.: A compact, high efficiency contra-rotating generator suitable for wind turbines in the urban environment. *Renewable Energy*, Vol. 35, No. 9, pp. 2027-2033, 2010.

[5] DANNECKER, R.K.W., GRANT, A.D.: Investigations of a building-integrated ducted wind turbine module. *Wind Energy,* Vol. 5, No.1, pp.53-71, 2002.

[6] KILLA, S., SMITH, R.F..: Harnessing Energy in Tall Buildings, *Bahrain World Trade Center and Beyond.* [Online], Available: http://global.ctbuh.org/resources/papers/download/464-harnessing-energy-in-tall-buildings-bahrain-world-trade-center-and-beyond.pdf [24 Nov 2016], 2008.

[7] *The home as micro-power station Part 2* (Eco-Refurbishment), [Online], Available: http://what-when-how.com/eco-refurbishment/the-home-as-micro-power-station-part-2-eco-refurbishment [22 Nov 2016], 2016.

[8] THANGAVELU, S. K., MUTASHER, S. A., KENNY LAU, Z.H.: Design and flow velocity simulation of diffuser augmented wind turbine using CFD, *Journal of Engineering Science and Technology,* Vol.8, No.4, pp.372-384, 2013.

[9] MOSTAFAEIPOUR, A.: Productivity and Development Issues of Global Wind Turbine Industry, *Renewable and Sustainable Energy Reviews,* Vol.14, No.3, pp.48-1058, 2010.

[10] The qr6 Vertical Axis Wind Turbinehttps, , [Online], Available: http://www.quietrevolution.com/ [22 Nov 2016], 2016

[11] *Urban wind turbines, Guidelines for small wind turbines in the built enviroment*, [Online], Available: http://www.urban-wind.org/pdf/SMALL_WIND_TURBINES_GUIDE_final.pdf [20 Nov 2016], 2007

[12] *Wind Energy Integration in the Urban Environment - WINEUR,* [Online], Available: https://ec.europa.eu/energy/intelligent/projects/sites/iee-rojects/files/projects/documents/wineur_summary_slides.pdf [10 Sep 2016], 2016

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