Continuing urban development with sustainable buildings

Valerie Gramond and Marie-Danielle Vazquez-Duchêne

Résumé **Poursuivre le développement urbain avec des bâtiments durables**
Nous vivons la plus grande vague de croissance urbaine de l'histoire. Dans les mégapoles, les citadins passent 90 % de leur temps à l'intérieur des bâtiments. Plus de la moitié de la population mondiale vit maintenant dans les villes, et cette part devrait atteindre plus de 70 % d'ici 2050, comme c'est déjà le cas aujourd'hui en Europe. La densification de la population européenne dans les villes fait face à de sérieux défis. Selon Ralf Spettmann, président de Construction Chemicals, « *BASF maitrise la capacité de réfléchir en termes de solutions de systèmes intégrés. Il peut donc apporter des contributions précieuses pour permettre à la vie urbaine d'être saine à façon et valorisante pour l'avenir, en Europe et à travers le monde*. »
Cet article expose des moyens pour optimiser les petits espaces et les conditions environnementales extrêmes développés par BASF afin de répondre aux défis de la ville par l'utilisation d'un isolant thermique mince intelligente et d'un design pratique. Après sept années de recherche, le chimiste Marc Fricke de BASF et son équipe ont notamment développé un matériau isolant à haute performance, mince et léger, basé sur un aérogel organique qui se compose de 90 % d'air et qui sera bientôt disponible sur le marché.
Mots-clés **Isolation, aérogel, polyuréthane, porosité, centre posdoctoral JONAS, BASF.**

Abstract We are living the largest wave of urban growth in history. In megacities, urban-dwellers spend 90% of their time inside buildings. More than half of the world's population now lives in towns, and it is estimated that by the year 2050 more than 70% of this population will live in urban areas while nowadays is the case for the European population. The densification of the European population in cities is facing serious challenges. According to Ralf Spettmann, President of Construction Chemicals, "*BASF has mastered the ability to think in terms of integrated system solutions. It can therefore make valuable contributions to enable urban life to be shaped in healthy and life-enhancing ways in the future, in Europe and throughout the world*." This article exhibits ways to optimize small spaces and extreme environmental conditions developed by BASF in order to answer the city challenges by the uses of intelligent thin thermal insulation and smart design. For instance, after seven years of research, BASF chemist Marc Fricke and his team have developed a high-performance insulating material, thin and light, based on an organic aerogel that consists of 90% air which will be soon available in the market.
Keywords **Insulation, aerogel, polyurethane, porosity, postdoc center JONAS, BASF.**

BASF strategy for climate change

Through research and innovation, BASF supports his customers in nearly every industry in meeting current and future needs of society. The energetic transition implies a technological break to move on. Chemistry is a central actor of innovations such as new materials for energy efficiency, renewable energies or conversion and storage of energy.

All aspects are relevant to us – we look at the full lifecycle. When calculating the greenhouse gas (GHG) emissions linked to our activities, we consider the entire value chain (*figure 1*).

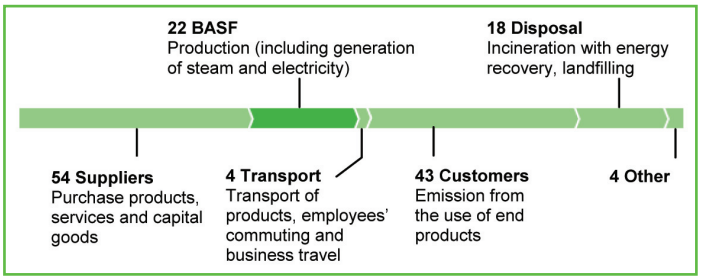

Figure 1 - Greenhouse gas emissions along the BASF value chain in 2015 (in million metric tons of CO_2 equivalents).

Energy Verbund

Historically, BASF is involved in the rationalization of resources especially with the Verbund concept. This system (applied at all major production sites) is a significant component of our energy efficiency concept: waste heat from one plant's production is used as energy in other plants. In this way, we saved around 17.6 million MWh in 2015 which correspond to 3.5 million metric tons of prevented carbon emissions.

It therefore offers us a crucial competitive advantage, while also having a positive impact on the environment. With our combined heat and power plants, we can meet 70% of the electricity demand of the BASF Group. We are exploring the use of renewable energies, and these can become a permanent part of our energy mix.

We take a holistic view: reducing emissions along the value chain

How can we reduce GHG emissions in our production and along the entire value chain? To this end, we have especially taken measures to reduce nitrous oxide in our production processes, and have been able to lower these emissions by 95% since 1997.

Cooperation with suppliers and use of intermodal transport is also key to save GHG emissions [1].

All operating divisions are engaged in this approach, including especially procurement, logistics, and production, R&D and Environment Hygiene and Safety. We offer our customers solutions that help reducing GHG emissions and improving energy efficiency.

Our goal is to continually increase the contribution of our current products and technologies for climate protection, as well as new products and solutions. We spend around one third of our annual expenditures for R&D on product and process innovations where the R&D target is related to resource efficiency and climate protection.

Our goals in climate protection

The BASF 2020 climate change goals are to reduce his GHG emissions per metric ton of sales product of 40% (BASF operations excluding oil and gas, baseline 2002). We achieved a reduction of 34.6% in 2015 (*figure 2*).

Corporate carbon footprint

BASF has been publishing a comprehensive corporate carbon footprint since as early as 2008. This report on all emissions along the value chain shows the volume of emissions prevented through the use of his climate protection products. We plan our climate protection activities along the value chain based on our carbon footprint.

The use of BASF products for climate protection purchased in 2015 is reducing our customers' emissions from 1210 to 680 million metric tons of CO_2, thus preventing 530 million metric tons of CO_2 emissions. Every product makes an individual contribution in the value chain. Assessing the value chains in terms of BASF's economic share of the respective climate protection product leads to the conclusion that on average, 11% of the emissions avoided were directly attributable to BASF's solutions in 2015 (the rest are indirect contributions) [1].

Our solutions: products for climate protection in construction

BASF products are involved in a large number of climate protection technologies. Therewith we enable energy efficiency and climate protection in a variety of sectors: transportation, energy storage and production, and construction such as building insulation materials.

Building and living

In line of our 2020 goals, we develop efficient and environmentally friendly insulation materials.

In our wide range of products, EPS board made of Neopor® is used as energy-efficient facade insulation and our chemistry research enables new products which are increasingly efficient as SLENTITE® which is a new PU aerogel (*figure 3*).

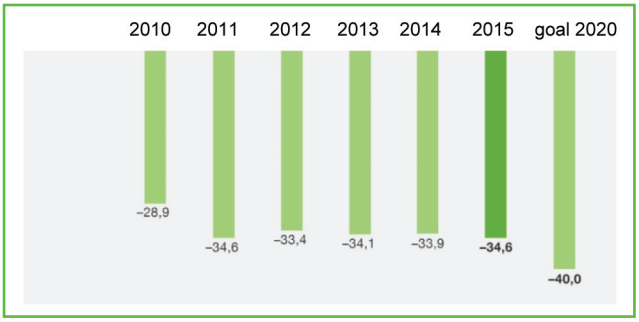

Figure 2 - Reduction of GHG emissions per metric ton of sales product in BASF operations excluding oil and gas (in %), baseline year 2002.

Figure 3 - SLENTITE® balanced on one finger.

Our products are used in several projects and we develop reference buildings to prove that it works. BASF has also developed his own energetic expertise as project owner. The BASF has its own real estate subsidiary that manages a fleet of 8.000 social housing at moderate costs for its workers based at BASF headquarters in Germany. From 2003 to 2006, 46 homes have been renovated to the "zero energy building" standards.

So we have built an integrated expertise in energy efficiency sector which allows us to intervene during the construction phase. And, with a feedback for ten years now, BASF increases the skills of French building professionals into "zero energy building" constructions and participates

in ten projects in different places in France both in new constructions and in renovation buildings [2-4]. The main aim is to create a new buildings generation of collective living which is accessible to everybody associating: good energetic performance, good cost rate/efficiency, and an architecture of quality with the famous architect Nicolas Michelin.

SLENTITE® material from BASF R&D

BASF provides a variety of smart products for perfect insulation. For various applications in the house building sector, BASF offers, for example, the time-proven, super-functional all-rounders Styrodur® and Neopor®. The Elastospray® system or insulating elements with flexible covering layers of Elastopor® and Elastopir® are especially suitable for pitched roofs, flat roofs and floor insulation. The excellent mechanical properties of these systems also allow them to be applied in areas with heavy compressive stress such as parking levels, patios or green roofs. BASF sets standards wherever there's a need for durable, economical and at the same time efficient installation for insulation of walls, roofs and floors.

Let's focus on the last innovation which is in the pipe of BASF: SLENTITE®.

Air provides excellent protection from the cold – which anyone can confirm when putting on his or her down jacket in the first days of winter. The tiny air pockets between the thousands of down fibers help the body to retain its heat. Like a down jacket, it has to be thicker to insulate better. But is it possible for insulation to be made slimmer without compromising on performance?

The innovation history

Just to identify the starting point of the innovation story, Marc Fricke began his work on this new material at the Institut de Science et d'Ingénierie Supramoléculaires (ISIS) at Strasbourg University (France), which is now part of the post-doc center JONAS (Joint Research Network on Advanced Materials and Systems) of BASF. This postdoc center incorporates four European partners: the ISIS-Institute, Freiburg University (Germany) and ETH Zurich (Switzerland) as academic partners, and BASF SE as the industrial partner. The close cooperation of three leading European universities with BASF enables all partners jointly to strengthen the research base of futuristic materials and systems and to expand it to the international research network.

"*Functional materials with new combinations of properties offer vast innovative potential. To realize that potential, we need both wide-ranging expertise and a creative interdisciplinary network to facilitate the development of inspiration and ideas and joint exploration of new themes. That is precisely what we hope to achieve through close cooperation with these top universities*" said Dr. Christian Fischer, now head of Performance Chemicals at BASF [5].

The cooperation will create approximately twenty new postdoc positions at the three universities with five main topics: monomers, polymers and materials, hybrid material systems, nanostructured systems, biobased polymeric materials and bioinspired systems. "*The diversity of the potential material innovations from this cooperation is immense, and the potential applications are equally wide-ranging*" commented Dr. Bernd Bruchmann, BASF Vice-President and head of the European JONAS center, adding that system solutions in thermal management, lightweight design and sustainable packaging are areas of interest.

Bionics is to be enlisted in the search for interesting materials and systems. "*We take a close look at the strategies Nature has developed to achieve certain effects, try to learn from those examples and put them to work in innovative technologies*", Bernd Bruchmann said.

Since 2003, BASF has been cooperating closely with the ISIS Institut, which was founded by Nobel laureate Professor Jean-Marie Lehn. The initiative created new opportunities in terms of collaborative research between university and industry.

For example, in 2015, the former postdoctoral candidate Nabarun Roy, now working with BASF Polyurethanes GmbH, has published an article together with Prof. J.-M. Lehn and Dr B. Bruchmann about dynamers (dynamic polymers) and adaptamers (adaptive polymers) for self-healing materials development and health care applications [6].

From the JONAS postdoc center to the R&D BASF, Marc Fricke started investigating highly porous, fine-pored materials over seven years ago. The finished product was a long way off. "*This was when BASF brought postdocs from all over the world together in the JONAS laboratory in Strasbourg. Equipped with all the necessary means, our job was to work on highly complex subjects. It was a question of developing new out-of-the-box chemical strategies or applying familiar strategies to new areas*", says Marc Fricke explaining the launch of the project culminating in SLENTITE®, the aerogel-based high-performance insulating material. "*At the beginning, we had no idea which direction we would ultimately take*" he adds.

What was already widely known at the time was that aerogels display extremely low thermal conductivity. What had yet to be developed was a process for bringing this extremely brittle material into a stable form. Aerogels in insulation were not new, but so far they had only be used as powders applied to a carrier material. The idea of Fricke and his team was to develop a pure polyurethane aerogel that can be produced as a sturdy panel, and that has more to offer than just insulation performance. "*That was a pretty tall order*", Marc Fricke recalls – and it still is, long after its achievement on the laboratory scale.

To understand the challenge facing the team, let's take a brief excursion into the world of chemistry. "*Imagine you're at home in your kitchen and you've made a jelly. The jelly has about the same consistency as our gel at the beginning of the process*", explains Nicholas Leventis, Professor of Chemistry at the Missouri University of Science and Technology and BASF cooperation partner. "*The task now involves replacing all the liquid in the jelly with air, and without the whole thing collapsing*." This is achieved with a process known as supercritical drying – something that gave Fricke and his colleagues plenty of headaches. "*It's essential that the material doesn't shrink and retains its shape and porosity*" stresses Marc Fricke, the only member of the team to have worked continuously on the project. "*Throughout the process that was just about the biggest obstacle we had to negotiate.*" Together with process experts of Hamburg University of Technology, they slowly inched toward the solution. The outcome is a PU panel consisting of an incredible 90% of air. It is trapped in myriad pores in the hundred-nanometer range and is very restricted in its movement – thus making the new aerogel panel one of the best insulating materials of the future.

The panel and its properties

SLENTITE® is therefore a real lightweight – heavier than polystyrene, but lighter than drywall. In addition it is extremely compression-resistant and easy to process: the insulating panels can be sawn, milled, drilled and bonded. Thanks to its open-porous structure, the material is also capable of absorbing and releasing atmospheric moisture – which is essential for a good indoor climate [7]. "*Because we can additionally reduce insulation thickness by 25 to 50%, we're opening up new opportunities particularly in architecture*" says Fricke, who is enthusiastic about his material. "*We can therefore address such urgent issues as the modernization of old buildings. And elaborate design solutions can be realized more flexibly with slimmer insulation*."

What is a nanostructured material?

The new material SLENTITE® is a polyurethanes that possesses 150 nm large pores, which are formed by a newly developed aerogel production process [7]. The pores trap air molecules and thus reduce the transfer of heat. As the pores are open, the material can take up and release moisture. This produces a pleasant room climate.

Knudsen effect inside aerogel (*figure 4*)

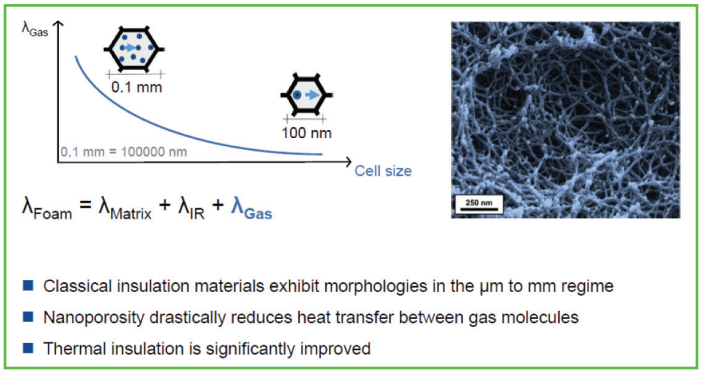

Figure 4 - The Knudsen effect.

BASF has started production of sample quantities in its pilot plant in Lemförde close to Osnabrück, Germany [8]. Potential applications will be in the construction and refrigeration sectors.

Open innovation

During the 150th anniversary of BASF, we have made efforts to communicate around a virtual platform Creator Space online with three challenges: food, smart energies and urban living. This platform is open to everyone who chooses to subscribe freely and share some commentaries on a specific topic or question.

In the same time of the BASF anniversary, three scientific symposia on food, smart energies and urban living took place respectively in Chicago, Ludwigshafen and Shanghai [9] (*figure 5*).

We would like to continue by finding a positive room to the open innovation. This could be with chosen temporary jamming session or specific open workshop with various

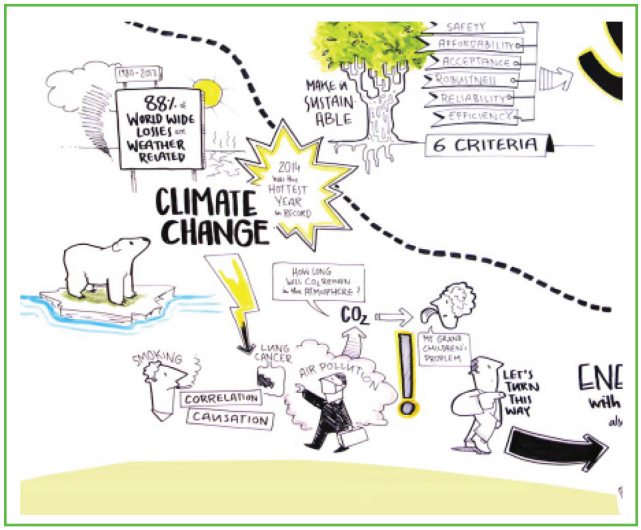

Figure 5 - From BASF Science Symposium, 2015.

skills as business manager, scientific expert and humanist or essayist…

Conclusion

Our strategy and these examples illustrate our responsible approach to energy and climate with respect to our suppliers, transportation, production and our customers. We have high standards and demand the same of our suppliers. That's why we combine economic success with environmental protection and social responsibility.

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V. Gramond

M.-D. Vazquez-Duchêne

Valerie Gramond is Governmental Affairs Manager - Urban Sustainability, BASF France*.
Marie-Danielle Vazquez-Duchêne (*corresponding author*) is Project Manager in Innovation and Sciences Relations-France*.

* BASF France SAS, 49 avenue Georges Pompidou, F-92593 Levallois-Perret (France).
Email: marie-danielle.vazquez-duchene@basf.com