# Using building simulation for moving innovations across the "Valley of Death"


JAN HENSEN
Professor, REHVA Fellow
Eindhoven University of Technology
j.hensen@tue.nl

ROEL LOONEN
PhD Candidate
Eindhoven University of Technology

MARIA ARCHONTIKI
Development engineer
Trespa International B.V.

MICHALIS KANELLIS
Postgraduate design engineer trainee
Eindhoven University of Technology


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## Using building simulation for moving innovations across the "Valley of Death"

The *Valley of Death* is known as a metaphor for the lack of resources and expertise that impedes new ideas in their transition from lab to market. This gap also hinders innovation and adoption of new technologies for improved energy efficiency in buildings. This paper presents why and how building simulation can help close this gap, and shows some examples.

A need for innovations in building envelope materials and components is at the heart of many technology roadmaps for sustainable buildings and cities, such as those recently issued by the International Energy Agency [1] and the European Commission [2]. It is expected that breakthrough developments in new facade constructions can make substantial contributions in the transition towards cost-effective nearly-zero energy buildings (NZEB) with high indoor environmental quality (IEQ). In particular, the potential of buildings with adaptable facades is identified as promising [3].

Advances in material sciences open up a growing range of opportunities for new building envelope technologies. Examples include vacuum insulation, phase change materials, complex fenestration systems and facade coatings with advanced properties. Most of these concepts start off as small projects in research laboratories. Typically, academic research groups can develop such concepts from discovery up to a point with a low technology readiness level (TRL) (**Figure 1**).

The subsequent phases of technology transfer and commercialization into marketable products and services, however, tend not to be straightforward [4]. Several reasons can be identified for this challenging situation:

- Basic research is mainly done with public funding, whereas private investors are mostly interested in working towards commercial viability. This leaves a void in the middle.
- The investment required in this area is generally high, but the certainty of success relatively low. Only few technology concepts will develop into successful commercial products.
- There is a lack of tools that can provide insights into building-integration issues in an early R&D phase (TRL 1-5). This results in a mismatch between information need and availability and complicates decision-making.
- The process requires an interdisciplinary approach. The right combination of skills and expertise may not always be available.

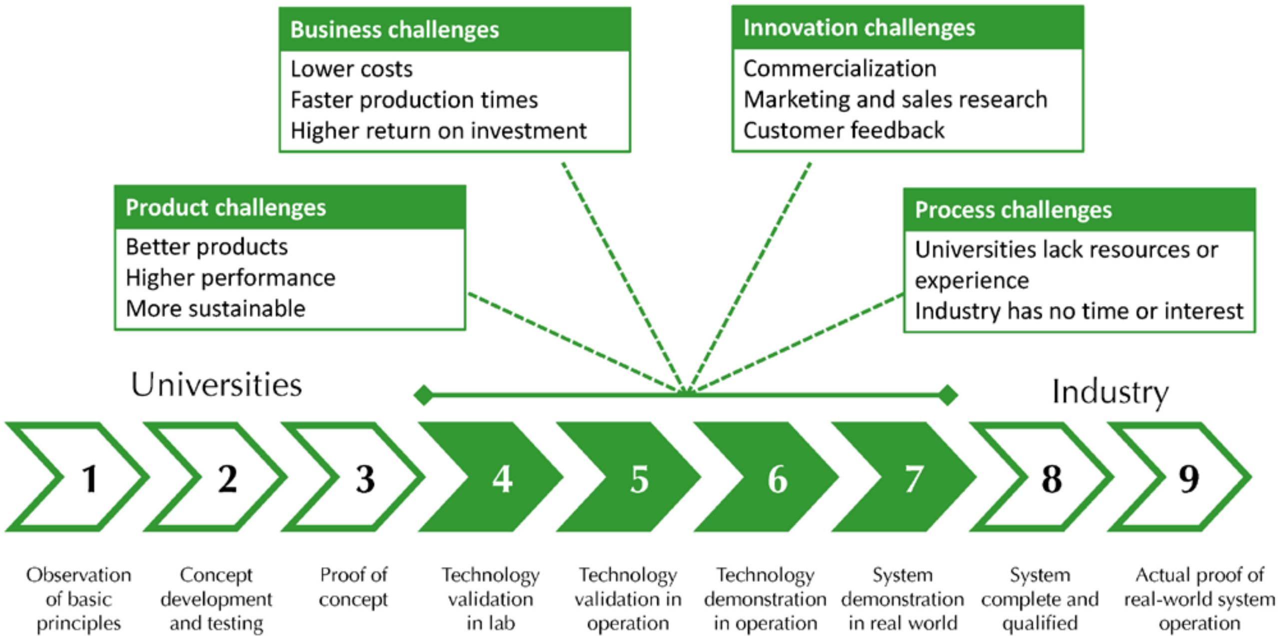


**Figure 1.** Overview of activities at different technology readiness levels (TRL). Details are given for some of the challenges at TRL 4 to 7.

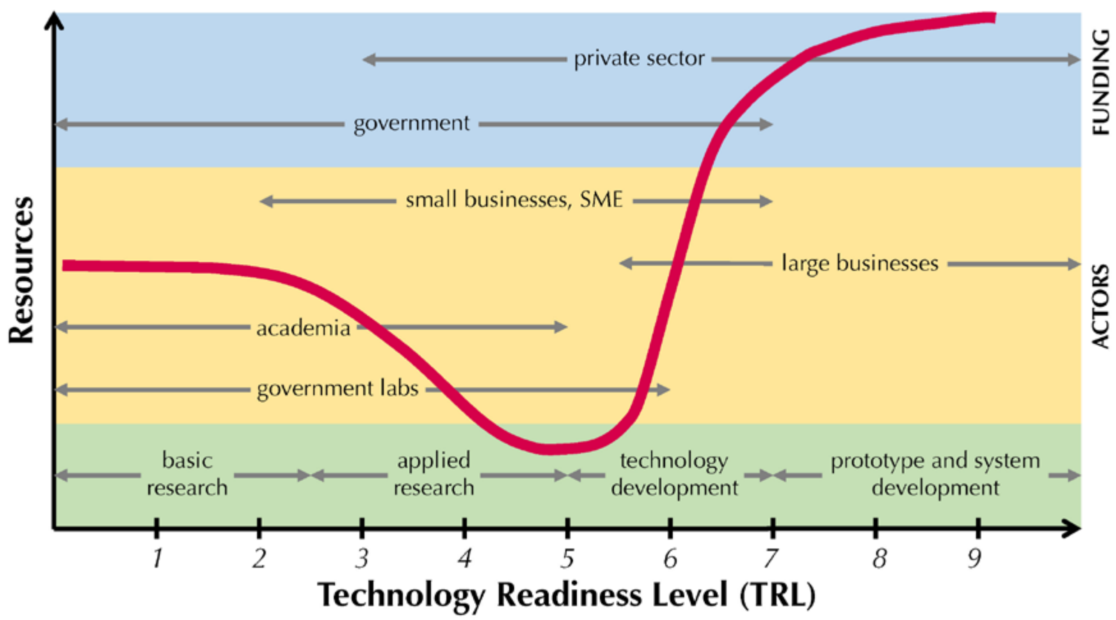


**Figure 2.** Availability of resources for new product development at various TRLs. The gap in the middle is sometimes referred to as "The Valley of Death"

The *Valley of Death* is sometimes used as an analogy to describe this discontinuity in innovation processes (**Figure 2**). Developing methods and tools that can bridge this valley is identified as an urgent stepping stone, and is therefore high on the agenda of policy programmes, such as Horizon 2020, the EU Framework Programme for Research and Innovation [2].

## Building performance simulation

Over the last few decades, building performance simulation (BPS) has evolved to become a well-established design support tool in the construction and HVAC design industry. BPS takes into account the dynamic interactions between a building's shape and construction, systems, user behavior and climatic conditions, and is therefore used as a valuable resource in many building design processes [5]. Because of these attributes, BPS can also be used as a tool for supporting informed decision-making in the R&D phase of innovative building envelope components, but such possibilities have only been explored to a limited extent [6].

Through iterative evaluation of multiple product variants, the integration of simulation allows for strategic decisions that acknowledge high-potential directions in the development process. What-if-analyses can be performed to evaluate the robustness of a new technology in many different usage scenarios and operating conditions. Moreover, BPS can act as a virtual test bed to assess the potential of materials with not-yet-existing properties. All these analyses can be done on the basis of relevant performance indicators, and as such, the method may help creating competitive advantage by improving product performance or time-to-market in a cost-effective way. This article discusses various applications of the use of BPS in two product innovation processes, and shows how it may stimulate future product development.

## Smart energy glass

Smart glazing systems, such as electrochromic or thermochromic windows, are identified as high-potential facade elements. By regulating the amount of daylight and solar gains they transmit, absorb and reflect, these windows offer options for improving energy performance and comfort conditions. A relatively high investment cost, but also technological issues, such the non-neutral colours, slow switching speeds and need for electricity supply, however, cause a relatively slow uptake in the market. To overcome these barriers, new switchable window systems, based on alternative physical principles are currently being developed. One of the emerging concepts is Smart Energy Glass (SEG) (www.peerplus.nl). SEG combines liquid crystalline materials together with window-integrated PV cells to create fast-switching, self-sufficient switchable glass (**Figure 3**).

Building simulations are embedded in ongoing efforts of scaling the technology from proof-of-principle to commercial building product, and focus on the whole-building integration issues of this high-tech product.


**Figure 3.** Smart Energy Glass – self-sufficient switchable windows.

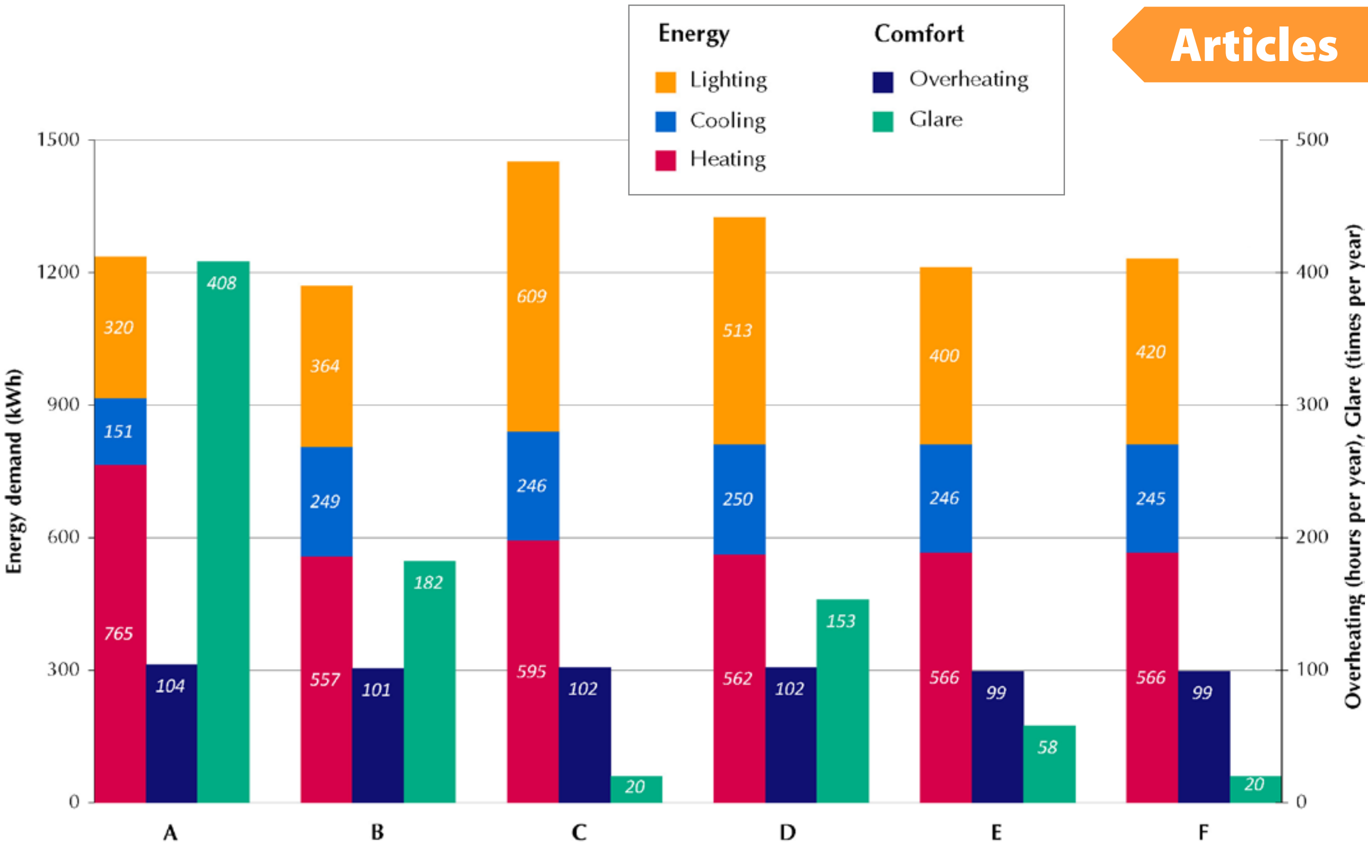


**Figure 4.** Performance of early-generation Smart Energy Glass (B-F) compared to a reference case (A). The different situations (B-F) show various types of control strategies.

The use of simulations started in a very early phase (TRL 2-3). At the time when the technology was only available in the form of small-scale samples, we used simulations to predict whole-building performance in terms of comfort and energy saving potential under a range of operating conditions and building use scenarios (**Figure 4**). Based on this information, benchmarks were set and specific material-level development targets were outlined. In addition, it served as justification for the decision to allocate more resources to the project.

In a later phase, we combined BPS together with sensitivity analyses and parametric studies. These structured design space explorations helped gaining information about the performance of a large number of possible product variants, without the need for having many prototypes. We identified, for example, that visual performance and glare discomfort are very important performance aspects. Development of switchable window coatings should take this requirement into account. In addition, the simulations showed that it is worthwhile to invest resources in the development of windows with properties that can be customized to the needs of specific cases. Sometimes it is needed to have high transparency in the bright state, whereas in other situations low light transmittance in the dark state is more important. Being able to adapt properties in response to case-specific requirements is the key to developing a successful product.

Finally, a dedicated software tool was developed, based on an extensive database of BPS outcomes. This web-based tool is used for communication with external stakeholders and potential clients. It stimulates discussion and facilitates decision-making, because the expected window performance can be visualized in a fast and easy way.

## Architectural Facade Panels (Trespa)

Trespa BV is recognized worldwide as a leading developer of high-performance cladding systems and architectural facade panels. An own research and development centre helps Trespa to stay ahead with innovative and sustainable products and design solutions. Building simulations form an integral part of this R&D strategy.

The case we present here concerns the challenge of reconciling architectural flexibility with the wish to achieve energy savings in sunny climates. Solar reflective properties play an important role in a building's energy balance. Highly-reflective surfaces reduce cooling load, but the light and/or shiny appearance that usually comes with high reflectivity is not always desired. By developing a spectrally selective finishing, Trespa aims at developing a solution that helps reduce energy consumption while allowing designers to use darker colours (**Figure 5**). Integration of building performance simulations was of definitive importance in assisting the whole development process, from the early stages of development until marketing and information dissemination stages.

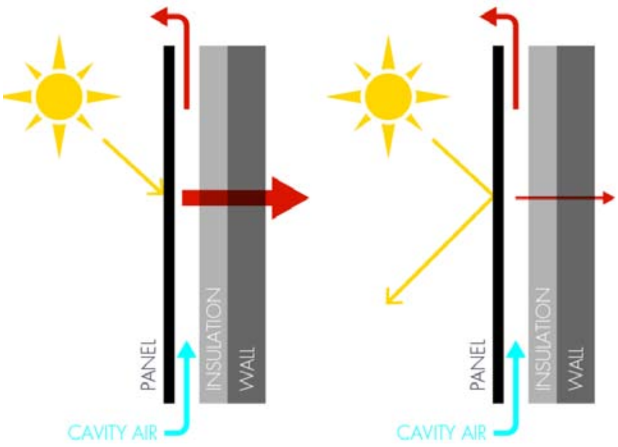


**Figure 5.** Conventional (left) and spectrally selective (right) facade coatings.

At an early stage of development, the reason for using building performance simulations was to evaluate the importance of various design parameters. By visualizing the governing performance trade-offs, this facilitated the selection among competing, potential product build-ups, based on their impact on a building's thermal load and economic feasibility.

Closer to commercial product launch, simulations also played a role. A study with a generic reference building was conducted to assess how the panels would perform in different locations all over the world. Based on the outcomes, and in consultation with the marketing team, the decision was made that the product is initially exclusively available for the Middle East and North African regions.

For a selected number of cases, more in-depth investigations of the energy saving potential of the new cladding system were made. These calculations served as input for financial calculations, to decide under which conditions application of the spectrally selective coating can be economically attractive. Afterwards, the results were correlated with the possibility of gaining credits related to energy savings, in popular green building certification schemes (LEED, ESTIDAMA). This is also valuable information for the customer and was included in the sales material.

## Conclusions and Outlook

Through a number of use cases, we have demonstrated how the application of building performance simulation (BPS) can support product development of new building envelope components, in both start-up companies and large multinationals. BPS adds many favourable opportunities to the innovation process, because it:

- can be used to inform decision-making from early R&D phases all the way through to marketing and sales support;
- is able to uncover the relationships between relevant whole-building performance indicators, that go beyond component-level metrics such as U-value or g-value;
- generates useful inputs for many types of subsequent analyses, such as life cycle assessment and financial business models;
- allows for testing multiple *what-if* scenarios in a virtual, and thus relatively inexpensive, way.

This focus on whole-building performance adds an extra dimension to the R&D process. BPS can be a useful resource for managing risk and uncertainty in product development, and thus increases chances that promising concepts successfully make the transition from lab to the market. We therefore argue that BPS should get a more prominent role in future R&D processes. ■

## References

[1] IEA, "Technology Roadmap - Energy efficient building envelopes," 2013.

[2] EC, "Energy-efficient buildings - Multi-annual roadmap for the contractual PPP under Horizon 2020," 2013.

[3] R. C. G. M. Loonen, M. Trčka, D. Cóstola, and J. L. M. Hensen, "Climate adaptive building shells: State-of-the-art and future challenges," ***Renew. Sustain. Energy Rev.***, vol. 25, pp. 483–493, Sep. 2013.

[4] E. Shove, "Gaps , barriers and conceptual chasms": theories of technology transfer and energy in buildings," vol. 26, no. 15, pp. 1105–1112, 1999.

[5] J. L. M. Hensen and R. Lamberts, ***Building Performance Simulation for Design and Operation***. London: Spon Press, 2011.

[6] R. C. G. M. Loonen, S. Singaravel, M. Trčka, D. Cóstola, and J. L. M. Hensen, "Simulation-based support for product development of innovative building envelope components," ***Autom. Constr.***, vol. 45, pp. 86–95, Sep. 2014.