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A contribution by Christoph Mitterer, Hartwig Künzel,
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Energy

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„Made in Germany“ is very popular in China and recognized as proof of quality. However, German approaches cannot always be transferred to other regions and cultures without adaptation. The German Passive House Standard for instance is such a German development which attracts more and more attention. Its principles support China in moving forward towards energy efficient buildings, which has already been demonstrated in many pilot projects. Yet, designers need to be aware that the methods, that are developed for and commonly used in Europe, may not be adequate for the greatly varying building practice and climate conditions in other countries.

The North American Passive House Institute (PHIUS) learned through practical experience that buildings which are designed according to the classic passive house standard still have a number of shortcomings in some US-American climate zones:

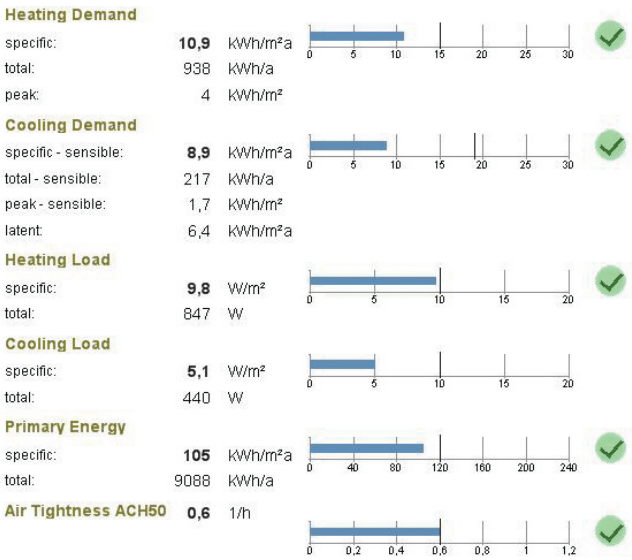
- Due to the different architectural traditions and other energy-cost structure in USA, the investment in high-performance insulation and other passive measures pays off more slowly than for example in Germany. Thus, acceptance and application tend to be lower.
- In hot and humid climate the energy-saving building style often results in uncomfortable conditions and sometimes hygienic problems due to insufficient dehumidification.
- Designing heating, ventilating, and air conditioning (HVAC) systems based on standard passive house calculations may underestimate the effect of daily load variations.

In various climate zones, hygrothermal assessment is a critical necessity: Improper hygrothermal design can quickly lead to catastrophic failure in the building

“德国制造” 在中国非常受欢迎并被认为是质量保障。然而德国的方法如果不能因地制宜的话，就无法总是成功地应用于其他地区和文化中去。例如德国的被动房屋标准就是这样一个越来越受关注的发展趋势。它的原则是支持中国向节能建筑转变，这在很多试点项目都得以证实。然而，设计师们必须要意识到，在欧洲发展和通行的方法可能不一定适用于其他国家各种各样的建筑实践和气候条件。

北美被动房屋研究院（PHIUS）通过实践经验了解到，按照经典被动房屋标准设计的建筑仍然在美国一些气候区域存在缺陷：

- 由于美国不同的建筑传统和其他能源成本结构，对高性能隔热层和其他被动建筑设施的投资回报比德国的例子更为缓慢。因此，被动房的接受度和应用程度往往也较低。
- 湿热气候的节能建筑风格常会导致不适的情况，有时不充分的除湿会引发卫生问题。



Passivehouse certificate criteria for Europe
欧洲被动房屋证书标准
Source / 图片来源: Fraunhofer IBP

structure. With high solar radiation, the lack of comfort assessment is also a significant issue which has led to serious overheating problems. Experiences show that a purely energetic consideration is insufficient to obtain buildings that are not only energy-efficient but also comfortable and permanently damage-free and resilient under extreme weather conditions.

Institutional players and authorities in China are aware that adaptations to the local requirements are necessary and thus they are working on appropriate standards for passive houses in China. Not only the revision of climate-specific building energy performance targets is challenging, also the computation method should be reviewed. The commonly used methodology for the energy concept design of Passive Houses is the static monthly balance calculation method. However, it neglects some influences which do not affect very much the performance of buildings in cold and temperate climates, but which might have negative effects on the building performance in various parts of China with hot and humid climates.

Static calculation methods with limitations

The monthly balance-based method as it is for instance described in the DIN EN ISO 13790 (2008) norm depends strongly on overall heat transfer coefficients, temperature difference, and considered time periods for heating or cooling. The underlying equations describe the monthly averages of the thermal losses or gains through the building envelope with air-exchange and the internal gains and losses. As depicted in the upper semicircle of the diagram, static monthly energy balance calculation methods allow primarily assessing the performance of a building design in relation to the exchange of heat, air and solar radiation.

For an estimation of the total annual heating demand in moderate climate zones, this monthly method is often adequate. However, when it comes to hot and humid or mixed climate zones not only heating of buildings is relevant but also cooling and dehumidification need to be addressed. Buildings with very high requirements on comfort, energy efficiency and sustainability may not be appropriately designed with static calculation methods. They lack the ability to assess certain dynamic factors of the energy balance such as storage effects or ventilation profiles that occur under real conditions. For instance, it is impossible to assess the thermal time lag and related overheating in summer.

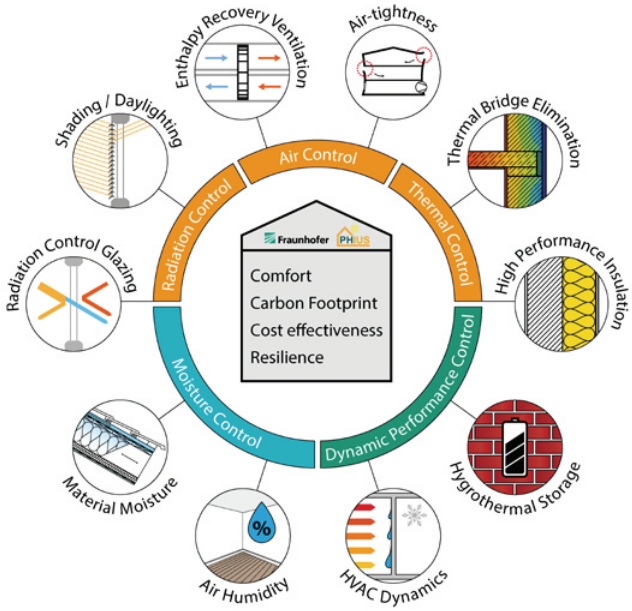
- 设计基于标准被动房屋计算方法的暖通空调(HVAC)系统可能会低估日负荷变化的影响。

在不同的气候区域,湿热评估是一个必要的关键因素:不当的湿热设计可能会立刻导致建筑结构的灾难性失效。太阳辐射较高时,缺乏舒适性评估也是一个显著的问题,会导致严重的过热问题。经验表明单纯的能源的考量不足以使得建筑不仅节能,而且舒适,同时在极端天气条件下长久免遭灾害并迅速复原。

中国政府和机构意识到因地制宜的必要性,因此他们在制定适合中国的被动房屋标准。具有挑战性的不仅是修订不同气候特性的建筑节能目标,还有改进计算方法。被动房屋节能设计通常使用的方法是静态的月平衡计算法。然而它忽略了一些对寒冷及温和气候区的建筑节能影响不太大、但对中国很多湿热气候区的建筑节能有强烈负面影响的因素。

有局限性的静态计算方法

以月平衡为基础的方法,以在DIN EN ISO 13790 (2008)标准中的为例,强烈依赖于总体传热系数,温度差,并考虑供暖和制冷的时期。基本方程描述了建筑外墙通过和外界的热交换损失或获得的热量以及内部热损失和热获得的月平均值。正如下图中所描绘的上半个圈,静态月能源平衡计算法允许主要评估建筑设计的关于热交换、空气和太阳辐射的性能。



Principles of passive building design
被动式建筑设计准则
Source / 图片来源: Fraunhofer IBP

要估计温和气候区的全年热需求,这种月平衡法通常足够了。然而当涉及到湿热地区或混合气候区,不仅

There are considerable limitations of static monthly balance methods, especially for building design in mixed and hot and humid climate zones:

- Static calculation methods are clearly limited in assessing cooling loads and cooling demands as well as related dehumidification requirements accurately. In those cases, dynamic simulation should improve the design by assessing thermal time lag more accurately.
- Solar radiation generates frequently comfort issues such as overheating in the shoulder seasons. Continuous comfort cannot be ensured based on static calculations.
- Static energy balance methods are unable to address moisture control in energy efficient buildings and building components. The appropriate envelope design for different climate zones from very cold to hot and humid requires distinctly different approaches regarding air tightness and moisture control layer within building components.
- Multi-zone modeling with interaction of the zones of more complex buildings such as a mixed-use larger building is not possible.

Dynamic hygrothermal whole-building simulation

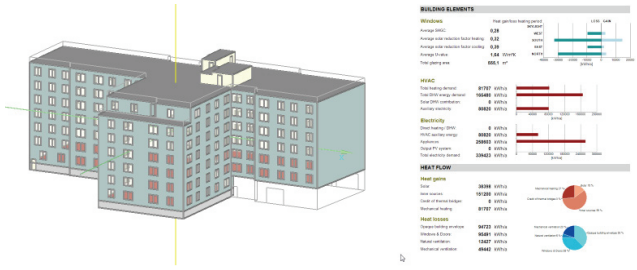
As depicted in the lower semicircle of the diagram a professional building simulation should also address the dynamic behavior and the moisture management in building components and rooms. This is especially important in climates where cooling and dehumidification of the indoor air play an important role. Dynamic heat and moisture processes in the building and in building components influence the energy demand as well as comfort and durability qualities. Effects of thermal inertia need to be taken into account as well as moisture buffering. The common static calculation tools ignore hygrothermal interaction between a building's interior and its envelope. The more detailed consideration of dynamic processes in a dynamic hygrothermal whole building simulation aims at further reduction of the energy demand, elimination of limitations in indoor comfort (overheating or overcooling for example) and avoidance of possible damage.

In addition to accounting for the thermal response of buildings and building components it is necessary to also understand the moisture conditions and the

是建筑的供暖，制冷和除湿问题也要解决。设计高度舒适性、节能和可持续要求的建筑可能使用静态计算方法设计就不太合适。它们缺乏评估某些能源平衡的动态因素的能力，例如在实际条件下的存储效果和通风效果。它不能评估夏季的热延迟和过热问题。

静态月平衡法有相当大的局限性，特别是在混合和湿热气候区的建筑设计中：

- 静态计算法在评估制冷负荷和制冷需求以及准确评估除湿需求方面有明显的局限性。在这种情况下，动态模拟应该通过更准确地估算热延迟来改善设计。
- 太阳辐射经常会影响舒适性，比如过渡季节的过热。静态计算不能保证连续的舒适性。
- 静态能量平衡法无法解决节能建筑和建筑构件的湿度控制。对于不同的气候区，从严寒到湿热，需要完全不同的方法来完成合适的外墙设计，具体包括建筑构件的气密性和防潮层。
- 无法完成对具有区域间相互作用的综合型建筑（如多功能大楼）的多区域建模。



Multi-zone model for a passive house
被动房屋的多区域模型
Source / 图片来源: Fraunhofer IBP

动态湿热整体建筑模拟

如前图中所描绘的下半个圈，专业的建筑模拟也应该处理动态行为以及建筑构件和房间的湿度管理。这在室内空气的制冷和除湿比较重要的气候区显得尤为重要。建筑和建筑构件的动态热湿变化影响了能源需求以及舒适度和耐久性。在湿度缓冲中也要考虑到热惯性的影响。常见的静态计算工具，忽略了建筑内部和外墙之间的湿热交换。在动态湿热整体建筑模拟的动态过程中更具体的考量，是为了进一步地减少能源需求，改善室内舒适度的不足（如过冷过热），以及避免可能发生的损害。

effects of humidity. Long-term exposure to high humidity can cause damage in building components, and also significant health problems may result from mold growth on humid surfaces. Furthermore, hygrothermal whole-building simulation allows a detailed depiction of user behavior while common static tools neglect cultural and climatic differences by using average values. Dynamic calculation methods allow designers to compare different building concepts for mitigation of humidity problems already in the planning stage. Moreover it is also important to consider the dynamic assessment of thermal protection for summer conditions. Since simulations are based on user-specified climate and on user-defined ventilation, HVAC and internal loads, the simulations can accurately predict the situation at hand.

PHIUS combines static and dynamic hygrothermal calculation

In March 2015 PHIUS+ 2015 – a climate-specific passive building standard for North America – was developed as the result of a research project conducted by PHIUS and its partners supported by the U.S. Department of Energy's (DOE) Building America grant. The new standard yields ambitious but attainable climate-specific building energy performance targets that substantially cut carbon emissions and energy consumption in buildings that provide superb comfort, indoor air quality, and resilience.

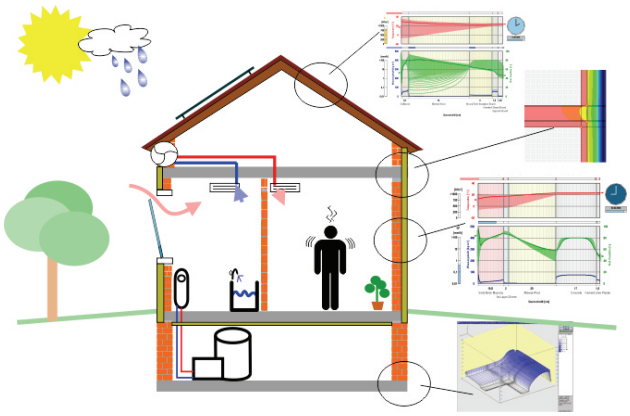
Designing such buildings requires specialized design tools to achieve targeted performance and quality assurance. The tools must enable the designer to meet the energy performance criteria of the envelope and the appropriate mechanical systems and – critically – to guarantee proper moisture control performance of all systems before the detailed construction design phase. The hygrothermal analysis reduces the risk of potentially catastrophic design flaws, thereby reducing the risk of moisture related problems for designers, builders, and building owners.

PHIUS and Fraunhofer IBP jointly developed a software tool which couples the balance-based method currently employed to design passive buildings to hygrothermal whole-building simulation software. Using PHIUS data and expertise, developers at Fraunhofer IBP were able to produce a simulation tool suited to North America's large variety of climate zones. The comprehensive output of simulations enables the planner to determine if the building meets passive house criteria and run further building performance

除了计算建筑和建筑构件的热响应，了解湿度情况和它的影响也是很重要的。长期暴露在高湿度条件下可能导致对建筑材料的损害，潮湿表面的霉菌生长也会导致显著的健康问题。此外，整体建筑湿热模拟允许对用户行为做一个详细描述，而常见的静态工具采用平均值，忽视了文化和气候的差异。动态计算方法使设计者能够比较不同的建筑理念，早在规划阶段缓解湿度问题。此外，考虑夏季条件的热保护的动态评估也是很重要的。由于模拟是基于用户指定的气候和用户定义的通风，暖通空调和内部负荷，因此模拟可以准确地预测手头的情况。

PHIUS结合静态和动态湿热计算

2015年3月，北美被动房屋研究院及其合作伙伴在美国能源部（DOE）的专款支持下，作为一项研究项目的结果开发了PHIUS+ 2015，一项针对北美地区特定气候的被动房屋标准。新的标准产生了有雄心但可实现的特定气候建筑节能目标，大幅削减建筑的碳排放和能源消耗，提供卓越的舒适性，室内空气质量和可恢复性。设计这样的建筑需要专门的设计工具，以实现有针对性的性能和质量保证。这种工具必须使设计者能够达到外墙节能标准以及合适的机械系统，更严格地说，在施工设计过程之前保证所有系统能够适当的控制湿度。湿热分析减少了潜在的严重设计失误的风险，从而对设计者、建筑者和业主来说减少了湿度相关问题风险。



PHIUS+ 2015 yields ambitious but attainable climate-specific building energy performance targets
PHIUS+ 2015产生了有雄心但可实现的特定气候建筑节能目标
Source / 图片来源: Fraunhofer IBP

北美被动房屋研究院和弗劳恩霍夫建筑物理研究所联合开发了一个软件工具，它将目前采用的设计被动式建筑的基于平衡的方法与湿热整体建筑模拟软件结合到了一起。使用北美被动房屋研究院的数据和专业知识，弗劳恩霍夫建筑物理研究所的开发者们就能

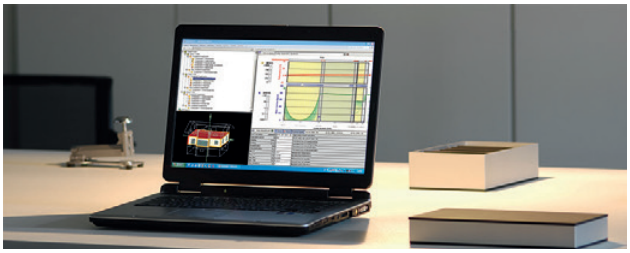
analyses within the same software tool. While the static monthly balance method simplifies the required steps and the time required to design a passive house, it might not be detailed enough to consider the different characteristics of all climate zones and building types. The results from a dynamic simulation are more precise and offer a more realistic depiction of the actual behavior of the building and its interaction with mechanical equipment in terms of comfort and energy efficiency. As the new created software dramatically improves the quality and efficiency of the design process, PHIUS has included in-class session on the software in trainings for Certified Passive House Consultants (CPHCs) since 2013.

The combination of both approaches into one tool has high potential to transform the passive building design process also in China by making very complex processes accessible to more design professionals. Passive buildings as well as other energy efficient buildings are also called Low-load Building which means that they generally have a low cooling demand. At the same time this represents a real challenge in climate regions with warm and humid summer conditions. Since the sensible cooling load is small, standard air-conditioning systems often fail to reduce the latent heat load appropriately. This results in high indoor humidity conditions which pose severe health risks and structural damage. Therefore, international efforts have started to solve this problem by adapting HVAC design based on the analysis of the dynamic hygrothermal behavior of the building envelope and the interactions of the user.

Problems with the latent heat load are one example that may be overlooked by the classic passive house design. However, this is not the only issue facing static design methods that work with monthly averages of the outdoor climate. As soon as the outdoor temperature gets close to the designed indoor temperature or swings around it, the building's thermal storage capacity and to a certain extend also its moisture buffering potential have great influence on comfort and energy demand. This calls for a detailed analysis of the building's performance which escapes static design methods. Therefore a revision of the current passive house design method appears to be important to assure good passive building design in the large variety of Chinese climate zones.

Further information about hygrothermal whole building simulation and climate-specific passive building design is available at our website.

够制作出适合北美各种气候带的模拟工具。模拟的全面输出使规划者能够判定该建筑是否达到被动房屋标准，用同一个软件还能进一步地运行建筑性能分析。尽管静态月平衡法简化了所需步骤和设计被动房屋的所需时间，但它可能不够详细，无法考虑所有气候区和建筑类型的不同特点。动态模拟的结果更加精确，并提供了更现实的对建筑实际表现和它与机械设备在舒适性和节能方面相互作用的描述。因为新开发的软件极大地提高了设计过程的质量和效率，自2013年来，北美被动房屋研究院将软件课堂包含在被动房屋注册顾问培训（CPHCs）中。



PHIUS and Fraunhofer IBP jointly developed hygrothermal whole-building simulation software
北美被动房屋研究院和弗劳恩霍夫建筑物理研究所联合开发了湿热整体建筑模拟软件
Source / 图片来源: Fraunhofer IBP

将两种方法结合到一个工具中在中国也有很高的潜力，通过为设计师们将复杂的过程化繁为简，来改变被动式建筑的设计过程。被动式建筑和其他节能建筑也被称为低负荷建筑，这意味着他们通常来说制冷需求较低。同时这在有着温暖潮湿夏季的气候区是一个真正的挑战。由于空调的显热负荷较小，标准空调系统经常无法适当地消除潜热负荷。这就导致了在室内高湿度条件下会产生严重的健康风险和结构损害。因此国际社会已经开始努力解决这个问题，基于建筑外墙的动态湿热性能和用户互动的分析来调适暖通空调设计。

潜热负荷问题是在经典被动房屋设计中很容易被忽视的一个例子。然而，这并不是使用户外气候月平均值的静态设计方法的唯一问题。室外温度一旦接近室内设计温度或在设计值周围波动，建筑的热容和它的调湿能力在一定程度上对舒适性和能源需求有很大影响。这就要求对建筑用静态设计法无法测量的性能做出详细分析。因此对目前的被动房屋设计方法进行修订对于确保在中国不同气候区设计良好的被动式建筑似乎是很重要的。

关于整体建筑湿热模拟和特定气候下的被动式建筑设计的更多信息请参见我们的网站。

For additional information about the building simulation software WUFI® Passive please visit www.wufi.com.

有关建筑模拟软件WUFI® Passive 的详细信息，请访问我们的网站 www.wufi.de/cn。