
展示房

澳大利亚零碳展示房

Australian Zero Emission Demonstration House

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1 背景简介

在澳大利亚，民用住宅已经成为碳排放增长较快的板块之一。预计在2020年，民用住宅将比1990年增加61%，因此，想要达到澳大利亚的以2000年为基准，在2020年和2050年相继减排5%和80%的目标，需要对将建的和已建的民用住宅进行大量的碳减排。2007年，为了倡导民用住宅的减排和维护国家未来的持续发展，澳大利亚联邦科学院（CSIRO）的能源转型研究中心设立了澳大利亚零碳房（AusZEH）项目，致力于展示和评估适用于澳大利亚的低碳民用住宅技术。

2 澳大利亚零碳展示房概况

澳大利亚零碳展示房项目的一个最主要的目标是设计和建造一个经济适用的零碳住宅，该住宅能产出足够的清洁“零碳”可再生能源以满足一个典型住户的能量需求，并且适合澳大利亚当地的气候及住户的生活习惯。更重要的一点是，该住宅还必须便于批量生产，从而能够推广到住房市场。为了这一目标，澳大利亚联邦科学院与业界重量级的地产开发商Delfin–Lend Lease和建筑商Henley Property Group联手，在零碳展示房联盟的协助下，在墨尔本市中心以北30km维多利亚州的Laurimar开发区设计和建造了第一所澳大利亚零碳展示房。

这一零碳展示房是由Henley Property Group在其现有的样板房中挑选并设计的一个典型的澳大利亚四室两卫双车库独立住

1 Introduction

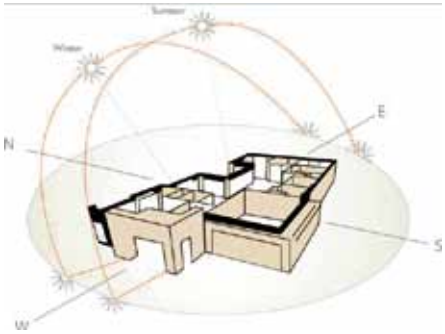
Energy use in buildings is responsible for 26% of Australia’s greenhouse gas (GHG) emissions and is the primary cause of peak energy demand on the electricity network. Nearly half of these emissions are produced from energy used in residential buildings. Although the residential building sector is not the largest contributor to GHG emissions in Australia, it is one of the fastest–growing sources due to population growth, the trend of smaller family sizes, and the desire for more comfortable indoor environment. Between 1990 and 2020 the number of households is forecast to increase by 61 %, from six million to almost 10 million. Consequently, to achieve Australia’s 5% and 80% GHG emission reduction targets in 2020 and 2050 respectively from the 2000 level requires dramatic GHG emissions reduction from both the new and existing residential building stocks.

In 2007, CSIRO’s Energy Transformed Flagship initiated the Australian Zero Emission House (AusZEH) project to demonstrate and evaluate how low carbon housing can be achieved in Australia to reduce GHG emissions from the housing sector and create a more sustainable future for the nation. As part of the AusZEH project, the first AusZEH Demonstration House is a 4 bedroom detached 8–star energy rated home that aims to deliver a residential home with a net zero footprint.

2 Overview of the AusZEH demonstration house

One of the aims of the AusZEH project was to design and build an affordable zero emission house – a house that produces enough clean, ‘zero emission’ renewable energy to supply all the operating energy needs of a typical household – which is suited to the Australian local climate, lifestyle and targeted to the volume housing market. CSIRO,

开放式起居、用餐、厨房



展示房朝向

宅。最初的设计草案由联邦科学院开发的澳大利亚民用住宅能级评定计算机模拟软件AccuRate进行了优化，通过对住宅的选材、朝向以及电器的选择进行模拟，达到了节能性能和成本的最优化。最后，针对这一设计和当地的气候，由在该项目中新开发的澳大利亚零碳房设计软件（AusZEH Design）计算出一个典型住户所需的太阳能发电容量。

澳大利亚零碳展示房的最终设计是一个八星能级的住宅，为了便于推广到批量住房市场，该住宅完全采用现有的建筑技术和可再生能源技术，配备先进的家庭能源控制系统，适宜当地气候，并且其造价符合澳大利亚中产家庭的购买能力。

3 澳大利亚零碳展示房的设计

为了达到零碳排放，该展示房采用了4种措施：设计住宅的节能性能以减少制冷和采暖耗能；选用高效的节能家用电器和配件；配备智能家庭能源控制系统用以优化能源利用；装备可再生能源发电。

3.1 住宅的节能性能

澳大利亚零碳展示房的总设计面积是240.9m^2，其中包括38.4m^{2}的双车库和3.6m^{2}的前廊，制冷和取暖的空间约占160m^2。展示房是当下比较典型的住宅设计，拥有4个卧室、宽敞的开放式起居/用餐/厨房空间、家庭影院、浴室、主卧室卫浴和洗衣间。澳大利亚统计局的数据显示，2007~2008年新住宅的平均设计面积是239m^2，维多利亚州新住宅的平均设计面积略高，达241m^2。

被动式建筑的基本原理提供了节能零碳住宅的设计基础，利用正确的住宅朝向、内部设计布局、保温隔热、热惰性及巧妙的门窗遮阳设计，使住宅取得较高的节能性能。

当前澳大利亚民用住宅采用十星能级体系（NatHERS），通过计算模拟一年的制冷采暖能量需求（MJ/m^2），将住宅评定成零到最高十星能级，零碳展示房取得了 NatHERS 8.2星能级。与5星能级的住宅相比，零碳展示房可以减少大约70%的制冷采暖

working alongside leading industry partners, Delfin–Lend Lease and Henley Property Group, and supported by the AusZEH consortium, has designed and built the first AusZEH demonstration house, which is located 30 kilometres north of Melbourne CBD, in the community of Laurimar, Victoria.

The AusZEH demonstration house was first designed by Henley Property Group, in consultation with CSIRO and Delfin Lend Lease based on an 'average' Australian house – four bedroom, two bathroom, double garage from Henley Property Group's existing design portfolio. The initial design was then further refined by CSIRO's AccuRate software, an energy rating system which uses computer simulations to assess the heating and cooling energy efficiency of residential building designs. The choice of building material, the house orientation and the choice of fittings and appliances were modelled to determine the energy performance and cost of different design options. The house design reflects the optimal balance between energy performance and price. From this design, the predicted total operating energy usage for the household was calculated using a new AusZEH Design software developed in this project. This determined the size of the solar panels required, which supply most of the electricity to meet the demand of the household.

The final design of the AusZEH demonstration house is an eight–star energy efficiency rated house with off–the–shelf building and renewable energy generation technologies, and new future–ready energy management technologies, matched to meet the design requirements for its location, and the budget of a typical middle income Australian family.

3 Design of the AusZEH demonstration house

To achieve the aim of zero emission, four main actions were taken:

Design an energy efficient home with minimal need for artificial heating and cooling

Incorporate energy efficient fittings and appliances

Incorporate smart energy management systems to control energy use

Incorporate onsite renewable energy generation to provide remaining energy requirements.

3.1 Energy efficient home

The AusZEH demonstration house has a total floor area of 240.9m2, including 38.4m2 for the garage and 3.6m2 for a covered porch. Conditioned spaces, those spaces that are subject to heating and cooling, account for around 160m2. The house incorporates four bedrooms, a large open plan living/dining/kitchen area, home theatre, bathroom, en suite to the master bedroom and a laundry and is typical of homes that are

保温夹心水泥地板聚苯乙烯保温块

展示房节能设计示意图

太阳能热水器

耗能，取得这一高节能性能是通过采用以下简单而有效的方法实现的。

（1）朝向和遮阳。因零碳展示房所处的当地气候是采暖耗能远大于制冷的需求，所以展示房的设计安排起居活动区域在北面（注：南半球太阳在北面）：冬天太阳较低，朝北的窗能让太阳辐射热充分进入室内；夏天太阳较高，加上朝北的窗的可伸缩遮阳帘，最多可以减少90%的太阳辐射热进入室内。

（2）木框双层玻璃窗和拉门。由于高至40%的采暖或制冷的能量可以通过玻璃窗损失，所以玻璃窗的大小及隔热性能至关重要。鉴于此，展示房使用了木框双层玻璃窗和拉门以减少采暖和制冷的能量损失。

（3）保温层。展示房使用了天花板R6和外墙R2.5保温层，并且外墙和屋顶包裹了反光膜以减少辐射热损失。展示房还采用了保温夹心水泥地板以进一步减少通过地基的热损失（保温夹心水泥地板是将聚苯乙烯保温材料夹在水泥地基里）。聚苯乙烯就是制作不烫手的咖啡杯的材料，根据同样原理，聚苯乙烯夹心水泥地板可减少通过地基的热损失。

（4）减少漏风。对于许多住宅，漏风是热损失的一个主要原因。由于在建筑施工时使用了简单的密封措施和优质的建筑部件，并且密切关注施工细节，展示房的漏风得到了很好的控制。

3.2 高效的节能家用电器和配件

为了实现整体性的节能效果，展示房使用了以下高效的节能家用电器和配件：

（1）照明。展示房使用了15W的节能下照灯以及LED下照灯，节能下照灯电耗约是白炽灯的25%。

（2）热水系统。展示房的平板式太阳能热水器可以提供一个家庭约75%的热水。

（3）制冷和采暖。展示房装备了热泵系统，这一分离式热泵可以提供16.3kW的供暖和15kW的制冷，该系统采用先进的技术，平缓地增加或降低功率以避免室内温度的波动。展示房分4个制冷和采暖区，可以按照需要单独分区采暖或制冷，既提供了

currently being built. Indeed, Australian Bureau of Statistics (ABS) data shows that for 2007/08 the average floor area for a new home was 239m2, with new homes in Victoria having a slightly higher average of 241m2.

The basic principles of passive design provide an excellent base to designing an energy efficient house. Through correct orientation and internal layout, appropriate use of insulation and thermal mass and well designed windows and shading, the house is able to achieve high levels of thermal efficiency.

The 10–star national home energy rating system (NatHERS) currently used in Australia assesses the thermal efficiency of the building envelope and calculates the required energy, in mega joules per square metre, to maintain the house within a prescribed comfort band. The AusZEH home achieves a NatHERS rating (using the AccuRate software) of 8.2 stars which equates to a saving of around 70% in heating and cooling energy requirements in comparison with a 5 star house. The systems employed to achieve this high energy rating were simple and cost effective and included the following aspects.

Orientation and Shading

Good orientation works on the basis of designing a home which takes advantage of its climatic and regional conditions. The AusZEH is located in a climate that requires more heating than cooling to keep the home at a comfortable temperature. The AusZEH uses the sun as a natural source of free heating during the winter (a.k.a: passive heating). The design makes the most of the suns warmth to heat the home with the living rooms' windows facing north. The windows transfer winter solar energy when the sun sits low in the sky and excludes summer sun when it' s sitting high above the house. The northern windows are also shaded from the hot summer sun using an extendable awning and exterior blinds. The exterior blinds are made from a fabric that reduces the sun' s heat by up to 90 per cent.

Timber frame double glazed windows to all windows and sliding doors

The balance between the size of the windows and the extent of the insulated wall is important as up to 40% of the energy used to heat or cool a home can be lost through the windows. In the AusZEH, timber frame double glazed windows have been used to reduce the heat loss and thus artificial heating and cooling energy consumption.

Insulation

Insulation acts as a barrier to heat flow and is essential to keep house warm in winter and cool in summer. The AusZEH has been built with R6 in the ceiling and R2.5 in the walls. Reflective foil wall wrap and roof sarking were also been used to reduce the radiant heat transfer into and from

太阳能光伏发电

家用能源控制系统触摸式屏幕

舒适的室内环境，又避免了不必要的制冷和采暖费用。

（4）烤箱和炉具。厨房烤箱和炉具也是家庭主要的耗能因素，展示房采用了高星级、低能耗的厨房用具。

3.3 太阳能发电

展示房屋顶装备了36块共6kW的太阳能光伏板，这些光伏板将太阳能转换成电能，经由直流变频提供家用或直接输入电网，展示房的家用能源控制系统可以同时精确地记录太阳能的发电和使用情况。

3.4 支持未来技术的智能能源控制系统

展示房配备了独特的家用能源控制系统，该系统由La Trobe大学和联邦科学院联合开发研制，可以同时精确地记录家庭用电和用水情况，使住户可以采取相应的节能措施，更有效地减少碳排放。

通过控制系统的触摸式屏幕，住户可以选择和控制室内照明、制冷和其他家电设备的运行。该控制系统与室外的天气监测站相连，可以显示当地天气，对比太阳能的发电和使用情况。此外，该控制系统还可以针对一系列不同的节能措施进行能耗、运行成本及碳排放量的评估，以便于住户做出有效的节能方案。同时，控制系统可以根据住户的自定义格式，生成不同时段各个房间和家电的（能耗）报表，随时传送到住户的手机上。

控制系统可以对家里的主要电器进行自动控制，比如电器待机电源的开启及关闭。更重要的是，这一控制系统支持未来家用技术，如可以兼容电动汽车充放电接口和“智能电网”。目前，该系统现已和维多利亚州最近正在推广的智能电表连接，能测量和记录展示房电能输出和输入。

4 一座住宅，一个家，一间实验室

零碳展示房现已租赁给一个澳大利亚家庭，在此后的一年里，联邦科学院将通过家庭能源控制系统监测其发电、用电、蓄电，以及碳排放的实际运行性能。通过比较零碳展示房与Laurimar开发区其他住宅的能耗及碳排放性能，积累经验，以便今后加以研究和改进。

the house. The AusZEH adopted insulated waffle pod slab foundation to further reduce the heat losses via the ground. An insulated waffle pod is an engineered slab design featuring a grid of internal beams created around polystyrene pods. This is the same material used in a take away coffee cup, and just like it keeps your coffee hot; it keeps this house warm by minimizing heat loss to the ground below.

Minimising air leakage

Uncontrolled air leakage is a major source of energy loss that contributes unnecessary cost to the heating and cooling of many homes. The cracks and sources of leakage in a house that allow conditioned internal air to escape to the external environment need to be controlled. The air leakage of the AusZEH has been minimised by the inclusion of simple sealing actions undertaken throughout the build and construction phase of the house. Essentially, the use of high quality building products and quality construction methods with an eye for detail, have resulted in significant improvement in the home’s air leakage performance.

3.2 Energy efficient fittings and appliances

In the AusZEH demonstration house, the following energy efficient fittings and appliances have been used.

Lighting

The AusZEH uses LED and 15 W compact florescent lighting (CFL) downlights which use around 25% of the power of halogen lights.

Hot water system

A twin flat panel solar hot water system is used to provide up to 75% of the hot water needs for the AusZEH.

Heating and cooling

The AusZEH has been equipped with a ducted inverter heat pump system. This split system has a heating capacity of 16.3 kW and cooling capacity up to 15.0 kW. It uses advanced technology that gently increases or decreases power until it reaches the desired temperature, maintaining it without great fluctuations. This technology in conjunction with the ZEH’s four zoned areas, optimise comfort levels while offering savings on running costs, as unnecessary consumption is eliminated by air conditioning only the areas needed.

Oven and stove

Kitchen appliances can consume a lot of power. The appliances at the AusZEH have high star ratings, which mean that they consume less power.

3.3 Onsite renewable energy generation

The AusZEH has been equipped with a 6 kW PV array of 36 solar panels mounted on the roof for on–site electricity generation. These solar PV produce direct current (DC) electricity which is then directed to an inverter that converts the low voltage DC to higher voltage alternating current (AC)

5 展望

从2004~2010年，澳大利亚的大多数州和地区对新的民用住宅相继制定了最低五星能级的节能规范，不过全国大约90%的现有民用住宅是在制定五星能级规范以前建造的，多数只是接近或低于二星能级。

可以预期，超过50%的现有民用住宅到2050年还将在使用，因此整个民用住宅板块减排的关键是对已建的民用住宅进行大量的减排。作为第二座零碳展示房，联邦科学院现正与维多利亚州政府联手将一栋旧的政府福利房翻修成零碳展示房。2011年的第三座零碳展示房——将维多利亚州的一个小区活动中心翻修改造成零碳展示房的工作也已开始酝酿。通过宣传和展示，这些零碳房的技术和经验将会在房地产开发商、建筑商和普通家庭中得以推广，预期在不远的将来，零碳房的技术将大幅度地减少澳大利亚民用住宅板块的碳排放。（Chen Dong/译，朱晓琳/校）

power. This AC current then goes back into the grid which is consequently tracked by the AusZEH Home Energy Management System to calculate the difference between the electricity used and produced by the AusZEH.

3.4 Smart and future ready energy management

The AusZEH demonstration house has been fitted with a unique Home Energy Management System (HEMS) which tracks energy and water use and supply. The HEMS, developed by La Trobe University in partnership with CSIRO, reduces household GHG emission by empowering the occupants to become more aware of their energy use and take action to minimise their household carbon footprint.

All energy and water usage information is displayed in the house on a touchscreen that can be accessed remotely via the internet or a mobile phone. Through the touch–screen, occupants can see at–a–glance how much energy is being used in different areas of the house, or by individual appliances. Lighting, air–conditioning and other appliances are also able to be controlled through the touch–screen. Linked to the on–site weather systems, the HEMS also displays the local weather conditions and tracks the amount of energy generated by the rooftop solar panels and compares this against energy consumption. The HEMS can also estimate and display energy, cost and emission savings from a range of energy–saving options, such as reducing stand–by power, or through more effective usage of heating, cooling and lighting systems in the house. It can provide customised reports of power consumption for different timescales, household appliances and zones and transmit this information in regular updates to the householder's mobile phone.

The system can intelligently control the main energy consuming devices in the home. It is able to automatically switch devices on and off according to a variety of operating schedules. For example, the HEMS can automatically switch off stand–by power in different parts of the house at a specified time of the day. Importantly, the system has been designed with the flexibility to allow future technology to be added. For example, it has the capacity to integrate a plug–in electric vehicle in to the home energy system. The system is 'smart grid' compatible and has been linked to smart meters to measure the energy flow into and out of the house.

4. A house, a home and a laboratory

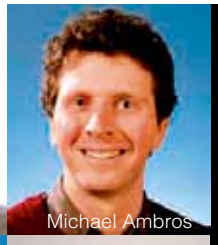
The AusZEH demonstration house is currently occupied by an Australian family for a year period and CSIRO will monitor the energy and water use, and GHG emissions over this time. Through the HEMS, detailed information will be collected on energy generation, consumption and storage and will be used to follow the energy flows and actual emission performance of the occupied house. The performance of the AusZEH will be evaluated against other homes within the Laurimar development to provide measurable, comparable information on the success of the project and help to identify key areas for further development.

5. Further Development

In Australia, most of the states and territories introduced 5 star house energy efficiency requirements between 2004 and 2010. Currently, around 90% of the existing national houses were built before the introduction of 5 stars. In fact, the sector is dominated by homes constructed before any energy efficiency or sustainability requirements were required and consequently, the majority of the homes rate poorly with energy rating around or below 2 stars.

It is anticipated that over half of today's housing stock will still exist in 2050. Consequently, in order to reduce the GHG emissions from the whole residential sector, it is critical to retrofit the existing housing stocks. As the second AusZEH demonstration house, CSIRO is currently collaborating with Victoria state government to demonstrate retrofitting technologies to achieve net zero emissions for an existing public residential house. A third AusZEH demonstration house project, retrofitting a community centre building in Victoria, is also started in 2011. It is anticipated that these demonstration projects and technologies will be adopted by the building industry and the general households and contribute to substantial GHG emissions reduction from the Australia residential sector in the future. AT


Greg Foliente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作者简介

Dr Greg Foliente，资深主任科学家，领导可持续性建筑环境及减缓和适应气候变暖的研究，曾获得多项奖励，包括美国土木工程师协会的 James Croes奖。

Michael Ambrose，资深科学家，是澳大利亚零碳展示房项目的主要负责人。

陈正东，博士，主任科学家，澳大利亚住宅能级评定技术委员会委员，领导住宅能级评定软件AccuRate的开发和研究，是自然通风微气泡模拟技术的发明人。

任振根，博士，从事绿色建筑研究多年，在澳大利亚零碳展示房项目中主要负责开发用于设计零排放房的软件，并运用该软件提供该展示房的节能方案和辅助工业合作伙伴达到零排放的目标。