



# Innovation to Improve Energy Productivity in the Shelter Value Chain



## AUTHORSHIP OF REPORT

### Authorship of report

This report is published by the Australian Alliance for Energy Productivity (A2EP). A2EP is an independent, not-for profit coalition of business, government and environmental leaders promoting a more energy productive economy.

The 2xEP program is an industry-led project to double energy productivity in Australia by 2030, supported by A2EP. 2xEP is guided by a Steering Committee of business leaders. An innovation working group, reporting to the committee (comprising 50 representatives of industry associations, researchers, companies and government agencies), provided significant input to the Next Wave. A2EP thanks members of the working group for their contributions.

The views expressed in this report are those of A2EP and do not necessarily represent the position of all individual working group members.

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In particular, the Board and staff of A2EP gratefully

acknowledge the amazing contribution made by Alan Pears.

We also acknowledge contributions of Mark Gjerek (Move3ment) and Michael Smith (Australian National University).

This document is a summary of The Next Wave Phase 1 Report, which is available at [2xep.org.au](http://2xep.org.au).

### ACKNOWLEDGEMENTS

A2EP would like to thank the following agencies for financial and in-kind support for this work:

- NSW: Department of Industry and Office of Environment and Heritage
- Victoria: Department of Environment, Land, Water and Planning
- Queensland Department of Energy and Water Supply
- Commonwealth: Department of Environment and Energy, and ARENA

Thank you for the support in the form of funds and/or people for the Next Wave.

Note: acknowledgement of this support does not indicate that these agencies endorse the views expressed in this report.



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## WHY THE 2XEP TARGET?

2xEP (a doubling of energy productivity by 2030 in the Australian economy) is a voluntary and aspirational target across the economy. It is a stretch target that will require changes in products and services, business models, attitudes and practices. We can reasonably expect that significant innovation will facilitate change and reduce costs.

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Energy productivity is now a clearly identified policy priority for federal, state and territory governments. Improving energy productivity is about increasing the economic value created per physical, as well as monetary, unit of energy consumed. In a period of increasing electricity and gas prices in Australia, in addition to volatility in the global oil market, a holistic approach to energy productivity can make a major contribution to Australia's overall economic productivity and, hence, competitiveness.

Energy is a substantial and growing cost to end-users – at \$110 billion nationally in 2013, this was equivalent to about 8% of Gross Domestic Product (GDP). The energy productivity project is directed to ensuring that every dollar spent on energy is economically effective.

## 2XEP AND THE NEXT WAVE

The Australian Alliance for Energy Productivity (A2EP) supports the 2xEP business coalition to double energy productivity in Australia by 2030. A key 2xEP project is the 'Next Wave', which explores opportunities for major improvements in energy productivity through innovation – deployment of new technologies and business models.

The Next Wave project developed a 'value chain' methodology to examine energy productivity opportunities. This process examines key energy using processes required to deliver end use products and services, applying a circular economy approach to energy and material flows. The Next Wave

project aims to define how to optimise these energy-using processes across the chain to maximise value created and reduce energy use.

## WHAT IS ENERGY PRODUCTIVITY?

Energy productivity is the value delivered per unit of energy. Economic productivity is a key driver of our international competitiveness and economic growth, and Australia's energy competitiveness has been plunging in recent years. In late 2015, COAG responded by establishing a target for improving energy productivity and a National Energy Productivity Plan. Initiatives to improve energy productivity will also be central to meeting Australia's international commitments to reduce carbon emissions.

$$\text{ENERGY PRODUCTIVITY} = \frac{\text{VALUE ADDED}}{\text{ENERGY}}$$

## NUTRITION AND SHELTER VALUE CHAINS

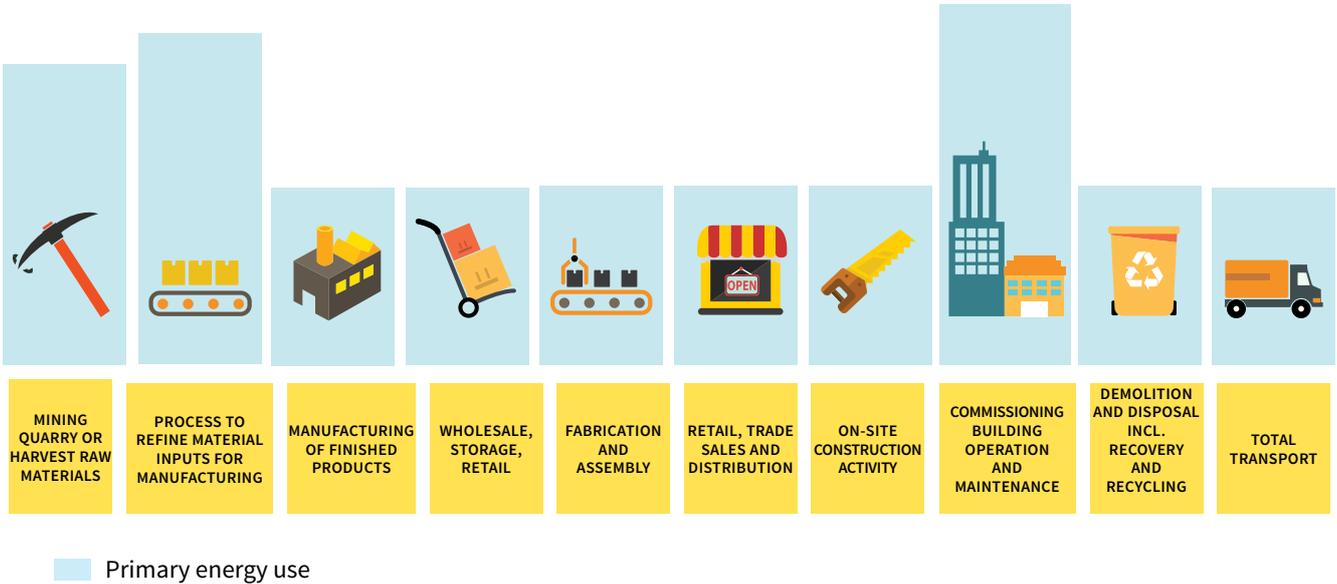
We selected two value chains to explore in the first phase of the Next Wave project:

food - from plate/export back to farm; and

shelter - focused on construction materials and embodied energy.

The Next Wave Phase 1 report includes an international scan of technologies and business models.

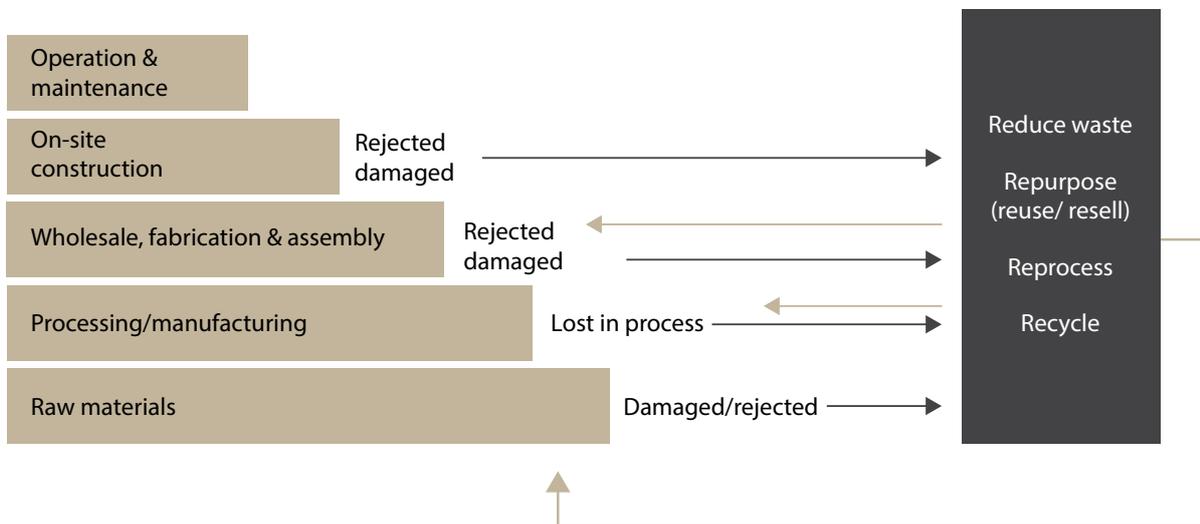
# PRIMARY ENERGY USE IN THE SHELTER VALUE CHAIN



The figure highlights the use of primary energy in the shelter value chain and key systems present along the chain. Primary energy is found to better correlate with carbon emissions and energy cost than final energy - the significance of using electricity (which involves input of three units of primary energy per unit of final energy) efficiently is emphasised.

# WASTE CYCLE AND MATERIAL FLOWS

Waste cycle in the shelter value chain highlights materials flows: as raw materials move upstream greater quantities of waste are generated. The waste and co-products have the potential to be reduced, captured, reused and repurposed. Reducing waste saves energy and resources along the whole value chain.



## KEY MESSAGES

- While energy for operation of buildings dominates lifecycle impacts, a focus on reducing energy and resource waste throughout the value chain is important, as significant benefits can be gained at each stage.
- Upstream processing for some materials also involves high temperatures and chemical processes which are more difficult to replace with zero carbon emission alternatives than operating energy. If developing countries use steel and cement for development in similar ways to past activity in developed countries, a large proportion of our global carbon budget would be used. Low emission building, material and infrastructure solutions must be found and implemented.
- For commissioning and operation of buildings, smart monitoring, diagnostics and management systems offer enormous potential for optimisation and fault avoidance, while advanced materials and technologies (e.g. cascaded heat pumps) and local/personal comfort provision systems can drive even larger energy productivity improvement.
- Many industries and businesses that provide inputs to the shelter value chain also provide materials, products and services for other sectors, so there is potential for significant flow-on effects from change in the shelter value chain.
- The shelter value chain can benefit by learning from other sectors and applying advances from them, ranging from advanced materials, new production models, software and smart systems.



<b>STEEL</b>	<b>CEMENT</b>	<b>PROCESSING TEMPERATURES</b>	<b>PREFABRICATION</b>	<b>WASTE</b>
Use of fossil carbon as a reductant in transforming oxides to metal can be replaced by electrolysis or renewably sourced hydrogen	Around half of the carbon emissions from Portland cement production result from chemical process so, unless cost-effective large scale carbon capture and storage can be implemented quickly, we need to shift to other materials, including other cementitious materials	Reduced by options such as ionic liquids, mechanical processes, 3-D printing etc. Where high temperatures are required, there is still substantial additional potential to recover and utilise high temperature heat for high value activities such as electricity generation	Using low impact materials such as engineered timber products and ensuring high thermal performance is fundamental to high material efficiency and optimal waste/material management and recovery	Landfills and materials in the existing stock of buildings and equipment are large and potentially valuable sources of high value materials. We must utilise these much more effectively, which involves improved separation and refining

Waste cycle and material flows

# Key systems to improve energy productivity

## LOWER ENERGY INTENSITY MANUFACTURING OF CONSTRUCTION MATERIALS

Steel, cement and bricks dominate energy use for manufacturing building materials, although glass, aluminium and other materials are significant.

### STEEL

Steel is used for roofing, reinforcing and other structural purposes and is a major contributor to energy used in this value chain due to its high energy intensity.

The scope for replacement or reduced use of steel within the construction sector, as well as across the whole economy, is substantial. A key factor influencing demand for steel is improvement in steel quality and strength. As improved alloys are developed and smarter production techniques applied less steel can deliver the same service.

Steel is also widely used for roofs and walls. Thinner, stronger panels and composites of steel and foam insulation allow larger spans between supports. New coatings and alloys extend the life of panels and replace energy-intensive galvanising processes, while the integration of solar PV means steel can provide a substrate for onsite renewable energy generation. 'Cool roof' coatings reflect more heat and extend the life of an existing steel roof at lower cost than replacement.

Large amounts of steel are now used for reinforcing in concrete.

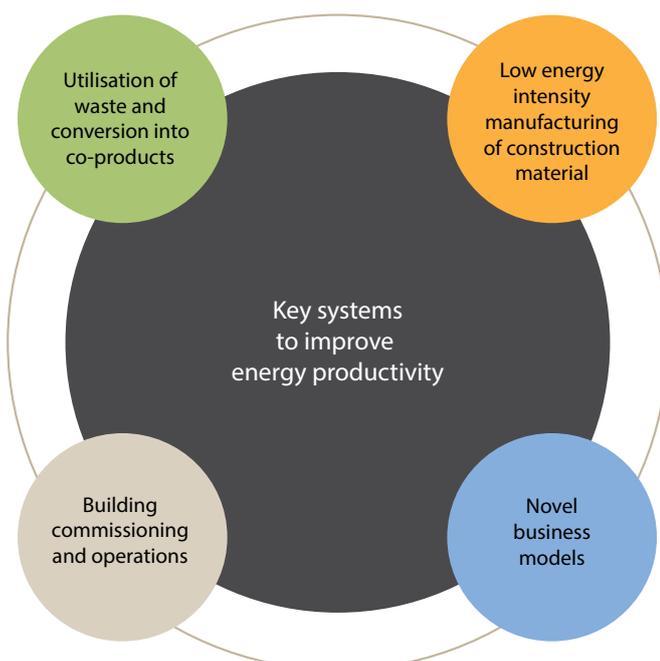
Alternatives such as fibre reinforced concrete could reduce steel use for this purpose.

### CEMENT

Cement production is energy intensive, and produces large amounts of CO<sub>2</sub> through the production process. Portland cement is typically blended with water, sand, aggregate or other materials to produce concrete, and often reinforced with steel to enhance its structural properties. The production of clinker from limestone is the major energy and carbon-intensive step in cement production, as calcium carbonate must be broken down, yielding calcium oxide and carbon dioxide. Heat energy is applied to drive this high temperature chemical process. Any changes that extend concrete curing time can increase construction costs. So actions aimed at reducing energy use in cement production must address significant practical barriers.

There are many ways to reduce cement use, for example:

- Encouraging the use of nature strips and green urban spaces with shade trees and permeable pathways that also reduce the urban heat island effect. Utilising water sensitive urban design that utilises natural hydrology rather than cement intensive trapezoidal stormwater drains;
- Utilise lightweight materials and insulation for foundations and flooring as an alternative to concrete slabs for homes. E.g. where thermal storage is important, phase change materials can provide this without adding significant mass;
- Replace Portland cement with low emission cementitious materials, such as geopolymers; and,
- Innovative alternatives to concrete such as cross-laminated timber construction, optimised design and prefabricated construction are reducing demand for concrete.



## UTILISATION OF WASTE AND CONVERSION INTO CO-PRODUCTS

Waste is produced at every step in this value chain and management of these wastes incurs costs and resources. There are significant opportunities to reuse, remanufacture or recycle steel, cement, aluminium, bricks, glazed windows, timber and furniture, when buildings are decommissioned or knocked down. It is possible to design and construct buildings to make it easier to re-use building materials. Green fit-out guidelines such as those used in the 60L Green Building in Melbourne, encourage reuse of second-hand materials and furniture.

Often, there is potential to convert a waste into a co-product. A waste from one sector may become a resource for another e.g. blast furnace slag from metal production into cements. Application of closed loop and industrial ecology principles help identify such opportunities.

Smart technologies offer potential to utilise waste in creative ways. New technologies can deliver high quality materials from waste (e.g. Case Study C), robotised systems to sort wastes more efficiently, and match availability of a waste (e.g. recovered structural beams in building waste) to potential customer demand. One research project concluded that 75% of steel and 50% of aluminium recovered could be reused without remelting.

## NOVEL BUSINESS MODELS

The report examines a large range of business model innovations that can offer radically lower requirements for energy intensive building materials. For example, prefabricated or 'manufactured' buildings, modules and components are becoming more widely used in Australia. They have been common in many other countries, often pioneered by firms outside the building industry. This approach offers many benefits over traditional on-site construction, including improved worker productivity, tighter quality control, shorter project times (with noise and amenity benefits for neighbours), reduced impacts of extreme climates, and so on. It is easier to incorporate energy efficiency features, as well as to build tighter buildings, along with tradie travel reduced, with flow-on reductions in road congestion.

## BUILDING COMMISSIONING AND OPERATION

This report focused on construction materials and embodied energy rather than building operation, because the 2xEP Built Environment Roadmap addresses issues relevant to building energy performance, and many other organisations have produced extensive analysis and policy development in relation to building operational performance. The report does provide an overview of how innovation could deliver major savings in building operation. See link [www.2xep.org.au/sectors/built-environment.html](http://www.2xep.org.au/sectors/built-environment.html).



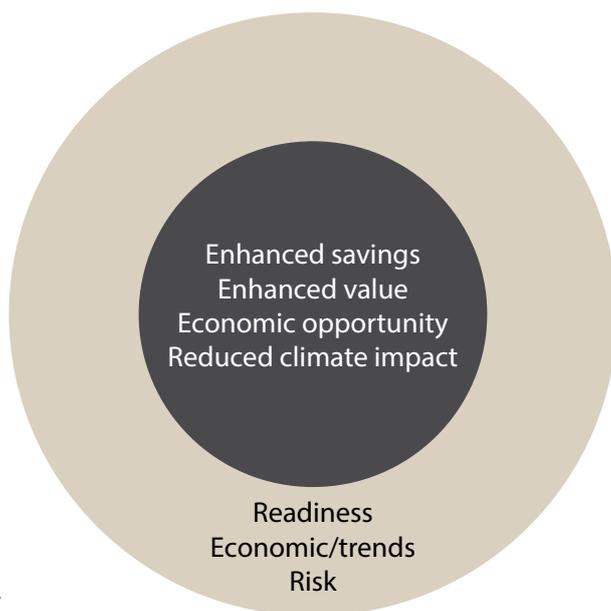
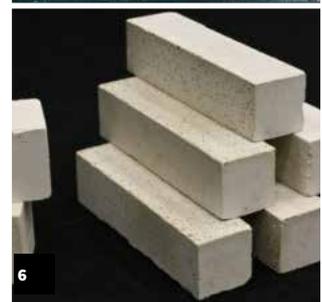
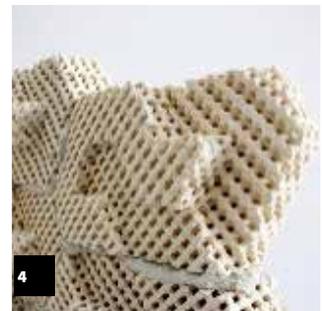
# ASSESSMENT CRITERIA AND HIGH POTENTIAL INNOVATIONS

The first two primary assessment criteria reflect the nature of energy productivity: improvement in value (or economic benefit) per unit of energy consumed. Using energy more efficiently or capturing greater economic benefit from energy consumed, or a combination, improves energy productivity. The third primary criterion considers interactions with the global economy and employment implications within Australia: this reflects the linkage of energy productivity to overall productivity, and productivity of labour and capital. The final primary criterion reflects the impact of innovations assessed on greenhouse gas mitigation.

The secondary criteria explore the practical issues involved in implementing the measures. The focus must be on technologies that are ready for commercial deployment, or will be within a few years, if they are to have a major impact by 2030. Many of the business model changes that

make the priority list actually use existing commercially available technologies, and the innovation is in the combination and deployment of these technologies in novel ways to gain energy productivity benefits, for example:

1. Prefabricated construction with engineered timber and other low impact materials
2. Increase recovery of high value material from building material waste
3. Utilise new technologies and business models to accelerate improvement of building energy performance
4. Promote optimal structural design and incorporation of emerging materials and systems into structures
5. Transition further to low emission steel production
6. Implement a cement emission reduction strategy



## CASE STUDY A

### **Construction materials with low embodied energy – geopolymer cement: Zeobond Group.**

Geopolymer cement is a viable alternative to Portland cement. Zeobond geopolymer cement has been used in a range of applications since 2006, including for VicRoads projects. Geopolymers are a type of inorganic polymer that can be formed at room temperature by using industrial waste as source materials to form a solid binder that looks and performs like Portland cement. The industrial waste products used in the Zeobond geopolymer cement are fly ash from coal fired power stations and blast furnace slag, the by-product of manufacturing steel.

[www.zeobond.com](http://www.zeobond.com)

## CASE STUDY B

### **Construction materials with low embodied energy – cross-laminated timber: Lendlease Forte.**

Cross-laminated timber has the potential to be deployed across the construction industry in residential and commercial applications. Timber panels undergo a process whereby they are stacked at right angles, bonded together and then hydraulically pressed. This process results in a construction material that is a viable alternative to concrete and steel that can withstand the same pressure as prefabricated concrete.

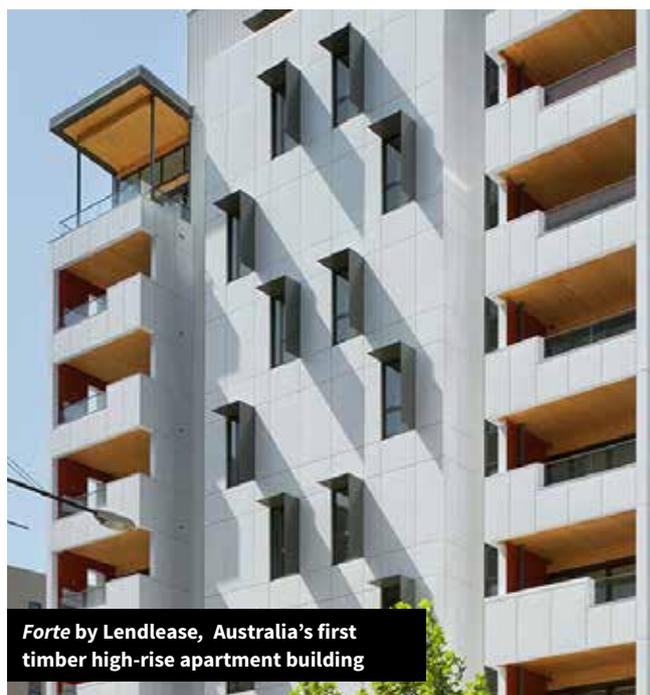
Lendlease constructed the 10-storey forte residential apartment building in Melbourne using cross-laminated timber and is currently constructing a commercial building in Barangaroo using the technology.

Life cycle analysis shows that the Forte building has a lower environmental impact on all assessed categories, except renewable energy demand, compared to the reference concrete based structures.

[www.lendlease.com/projects](http://www.lendlease.com/projects)



**Zeobond geopolymer cement**



**Forte by Lendlease, Australia's first timber high-rise apartment building**

## CASE STUDY C

### **Mining e-waste for valuable metals and construction materials sorting – UNSW Centre for Sustainable Materials Research and Technology.**

A drone is programmed to identify printed circuit boards, which contain many valuable elements, in waste stockpiles. The drone passes this information to an intelligent robot, which extracts the circuit board from the waste pile. The circuit boards are fed into a transportable micro-smelter that uses precisely controlled temperatures to produce copper and tin-based alloys and destroy toxins. This process is a low cost solution to transforming surplus printed circuit boards into valuable alloys and simultaneously destroying toxins. The micro-smelters may be taken to waste sites, reducing costs, energy use and emissions associated with transporting waste to large industrial scale smelters.

Large scale rollout of this process could result in cost-effective recycling of metals, reducing the quantity of virgin materials mined and stockpiles of toxic e-waste in landfill. The metal alloys produced by the process are valuable and would generate a source of revenue.

[www.smart.unsw.edu.au](http://www.smart.unsw.edu.au)

## CASE STUDY D

### **Innovative Business system – factory manufactured buildings – Habitech Systems.**

Factory fabrication housing based on a system of interlocking wall and roof components is an alternative to on-site construction of housing. Low embodied energy materials are employed including magnesium oxide cladding boards and plantation grown timber. The content of the cladding boards is 50% recycled timber. Production cost savings are realised through standardisation and mass production and minimisation of material and energy wastage when fabricating building components.

Modular systems allow components to be delivered in a flat pack format to maximise transport efficiencies, faster build than traditional construction methods (reducing financing costs), and providing standardised openings for lower cost standard sized multiple-glazed window. Factory manufactured buildings have the potential to be deployed across the construction industry in residential and commercial applications.

[www.habitechsystems.com.au](http://www.habitechsystems.com.au)



## ACTION PLAN

- 1. Commission further research, including economic analysis, into:**
  - Low energy methods of producing and utilising traditional building materials such as steel, cement and bricks;
  - Development and use of alternative, less energy intensive building materials as substitutes for traditional, energy intensive building materials; and,
  - Opportunities to increase rates of recovery, reuse and recycling of building materials.
- 2. Establish design hubs and support networks to encourage:**
  - Integration of energy/resource productivity into new products, materials, systems and business models, based on a circular economy approach.
  - Factory manufactured houses and commercial buildings, using prefabrication and Design for Manufacture and Assembly (DIMA) linked to distributed manufacturing of sub-modules and components using emerging techniques such as 3-D printing and materials such as cross-laminated timber to capture multiple benefits.
  - Optimal structural design integrating low energy/light materials into designs, fabrication and construction practices, e.g. tensile structures, blow-up structures, pre-fab construction, phase change materials (replace mass), aerogels, smart shading systems, ultra-low conductivity insulation materials, heat rejecting coatings and films.
- Improved design, specification and construction for smart, efficient, comfortable buildings with a low embodied energy, carbon footprint and zero net energy use in increasingly extreme climates.
- 3. Rewrite model specifications, standards, government specifications to drive low carbon, low material content, high efficiency options as priority choices.**
- 4. Develop techniques for extraction and upgrading of high value building materials from landfills and waste, including ways of avoiding need to remelt metals and production of energy from waste.**
- 5. Identify and implement effective mechanisms to ensure new and composite materials introduced into building construction are designed for reuse/recycling at end of life.**



## KEY CONCLUSIONS FROM THE NEXT WAVE – PHASE 1 PROJECT

- The value chain analysis process applied in this project is a valuable methodology for defining energy and resource productivity opportunities, and can provide an excellent overview of the flows and interactions of energy and materials and associated carbon emissions. This methodology can be applied equally well to other value chains.
- Doubling energy productivity is an achievable objective in the value chains reviewed. Innovation provides the scope to fill the gap from what can be done based on existing best commercial practices, provided business and governments take a proactive approach to accelerate change to gain the energy productivity benefits that are on offer.
- The best opportunities to significantly improve energy productivity have the following characteristics:
  - ◆ They are not incremental improvements – instead they apply new business models and often operate across sector boundaries.
  - ◆ They generally involve innovative and integrated applications of multiple technologies, which provide far greater benefits than individual technologies alone. The interplay between technologies amplifies and enhances the benefits.
  - ◆ They often involve both energy and materials savings e.g. dewatering and waste reduction decrease mass to be transported and processed.
- There are some windows of opportunity that must be exploited in a timely manner. For example:
  - ◆ The HFC phase out will drive increased turnover of refrigeration plant in the next 10 years. New refrigeration must be properly sized, smart and efficient.
  - ◆ New buildings have very long lives, so failure to incorporate high efficiency and adaptability ‘locks-in’ longer term higher emissions and costs, and a need for more investment in energy supply infrastructure that could be avoided.

- Innovation opportunities that will lead to significant job creation in Australia will generally be around targeted technical innovations combined with delivery of integration services, which can be exported. For example:
  - ◆ Expertise in using Internet of Things and cloud computing for optimising cold chains, and for optimising freight energy performance and logistics.
  - ◆ Integration of energy efficiency with renewables and storage, using Internet of Things to link them together
  - ◆ Building on international research into fundamental processes and new materials in new ways. Apply principles, design and adapt technologies and new business models into novel applications and solutions to deliver energy productivity benefits through products and services.

## NEXT STEPS

The full detailed report for Phase 1 of Next Wave Project, including the next steps for the project, can be found at

[www.2xep.org.au/innovation-the-next-wave.html](http://www.2xep.org.au/innovation-the-next-wave.html).

The *Food Value Chain Summary* and *Shelter Value Chain Summary* are also available for download [here](#).



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