Systems Thinking

A new approach to minimum energy performance standards

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ENERGY EFFICIENCY & CONSERVATION AUTHORITY

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Executive summary

The Government is committed to responding to climate change while securing an affordable, secure, and sustainable energy system for New Zealanders. Our *Energy Efficiency First: The Electricity Story* report found that by increasing the uptake of energy efficient technologies in factories, businesses and homes, the Government can reduce the need to construct additional expensive renewable energy infrastructure.

One lever for promoting the efficient use of energy is the use of minimum energy performance standards (MEPS). For almost 20 years, we have used MEPS to reduce energy consumption, remove poor performing products from the market, and assist consumers to make more-informed purchases.

A recent review of the regulatory system underpinning our MEPS programme recommended investigating a systems-approach to MEPS. Traditionally, MEPS require products to meet specified minimum energy performance criteria when tested under standardised conditions. A systems approach may enable us to expand our MEPS programme beyond residential products and provide greater emissions savings.

This report investigates how a systems approach to MEPS might contribute to a just transition to a low-carbon energy economy.

Contents

What we do

At EECA, we work to create positive change across systems, using a combination of three important levers.

Co-investing

We co-invest in energy-efficient technologies and renewable sources of energy

Regulating

We regulate proven technologies and processes by implementing Minimum Energy Performance Standards (MEPS)

Motivating people

We motivate people to make clean and clever energy choices

MEPS

Minimum Energy Performance Standards (MEPS) underpin EECAs most successful energy efficiency programme to-date, saving 50 petajoules of energy since 2002.

What are MEPS?

Product MEPS operate by specifying the minimum energy efficiency requirements (or maximum energy usage) for a given product class at the unit level. The performance of a product is measured in laboratory conditions according to the test methodology stipulated in the standard.

Increasing the stringency of MEPS eliminates the least efficient products from the market while increasing the levels that must be met for a product to be certified and encourages manufacturers to produce affordable high-efficiency products that households and businesses will recognise as good choices to lower their energy costs.

Success of MEPS in New Zealand

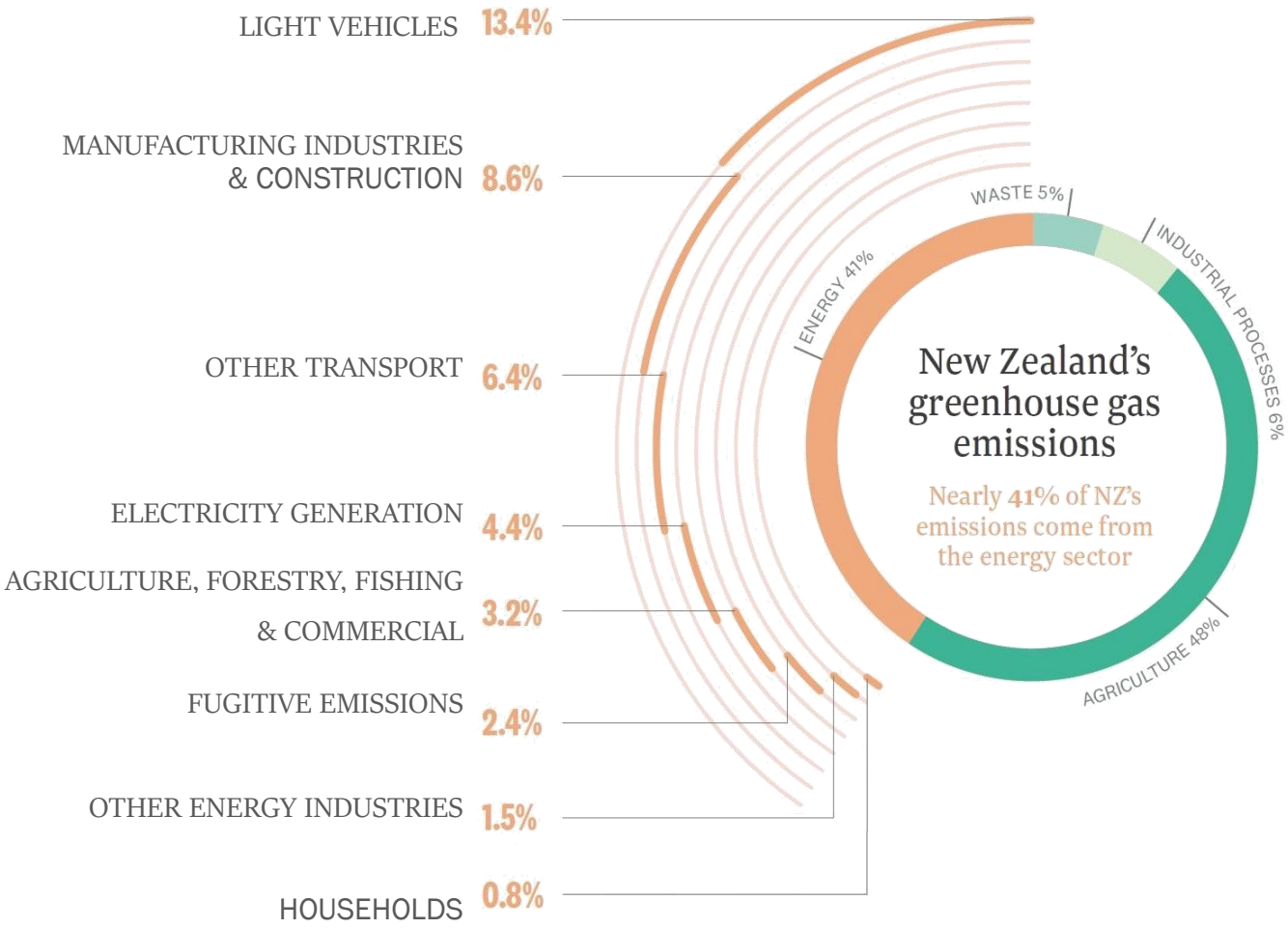
The Energy Efficiency and Conservation Act 2000 (the Act) permit regulations to be made that prescribe MEPS for energy-using products and services.

MEPS underpin EECA's most successful energy efficiency programme to-date. They have reduced operating costs, and contributed to a reduction in New Zealand's energy consumption and associated greenhouse gas emissions in the residential sector.

Since the Regulations were introduced in 2002, the 78 million regulated products sold in New Zealand have delivered 50 petajoules (PJ) in energy savings, prevented 1.98 million tonnes of GHG emissions and accrued $1.23 billion in national benefit.

Emissions and energy

Electricity generation and households account for less than 6% of New Zealand's greenhouse gas emissions.



What do we regulate?

Currently, we regulate 20 different products, primarily from the residential sector. As a programme best suited to off-the-shelf residential products, MEPS have had the greatest effect on electricity consumption.

Product-MEPS limitations

Electricity-centric

While home appliances are a large and growing area of energy consumption,[1] electricity generation and households account for less than 6% of New Zealand's greenhouse gas emissions.

Residential-centric

Once all regulated appliances have been considered there is only 46 per cent of residential energy consumption remaining.[2] Including the appliances currently under consideration for regulation reduces the remaining residential energy consumption to 9 per cent.[3] The set of appliances represented in this grouping are quite diverse and individually do not constitute a significant amount of energy consumption within the sector.

Normalised testing

Once a product has been installed, the energy performance changes according to the conditions, which will inevitably vary from the standardised laboratory test conditions.

For example, a gas combination boiler designed to be used in combination with solar collectors for water heating and space heating may lead to an inefficient system if installed only to heat water.

Additionally, depending on its application and the interactions the device has with other components of the system, product MEPS levels may not lead to corresponding improvements in the performance of the overall system. Typically referred to as the rebound effect, the behavioural or systemic responses to technologies that increase the efficiency of energy use can reduce or reverse the expected efficiency gains.

Embodied energy

Product MEPS are end-use focused. In some cases, the embodied energy —what is required to increase the efficiency of the energy service in the first place - may mean a product designed to use energy more efficiently is actually more inefficient overall.

Complexity

MEPS at the product level need a certain level of simplicity to be effectively implemented. One of the reasons MEPS have not been implemented for industrial products is that industrial products are often made up of many different components, which would all require

[1] Cabeza, L. F., Urge-Vorsatz, D., McNeil, M. A., Barreneche, C., & Serrano, S. (2014). Investigating greenhouse challenge from growing trends of electricity consumption through home appliances in buildings. *Renewable and Sustainable Energy Reviews, 36*, 188-193.

[2] *Energy Consult. (2015). Residential Energy Baseline Study: New Zealand.*

[3] Ibid.

individual standards to make any significant difference. Additionally, many large industrial products are bespoke, which has made it difficult to design single standards for MEPS and testing requirements.

Trade

Under the Trans-Tasman Mutual Recognition Arrangement (TTMRA), a product that can be produced or imported in Australia can be legally sold in New Zealand.

As a result, product MEPS are developed in conjunction with Australian Commonwealth, state and territory governments. While this reduces the cost of policy development, compromises can be necessary to suit both countries.

Can MEPS be better utilized?

For the first time since they were introduced, EECA commissioned a review of the effectiveness of the regulatory system to identify issues that are preventing the optimal energy and emissions savings.

One of the main conclusions of the Review was that product MEPS are only able to capture a limited portion of the energy-using market in their current form.

The *Review of Energy Efficiency Regulations* (the Review) recommended investigating a system-based approach.

Energy systems

"Taking a systems-based approach would encourage innovations leading to improved reliability of products, reduced life-cycle costs and increased energy efficiency."

The Review of Energy Efficiency Regulations

A systems approach to MEPS looks beyond the energy performance of the product and focuses on the interaction between each component and process.

The idea of applying a systems-approach to energy efficiency policy arises from the growing recognition that the performance of a complete system is more important than that of its individual components.[4]

What is an energy-using system?

An energy system is comprised of a sequence of conversion and transportation operations that bring energy in the appropriate form to the required place.5

The performance of a system is dynamic and changes according to conditions of use, maintenance, and component upgrading. While technically complex, the general formula of the energy efficiency (η) of a system is simply defined as the ratio between the service output and the energy input:

$$\eta = SOUTPUT/EINPUT$$

De Beer distinguishes two energy sub-systems based on delivery and end-use. In the energy supply sub-system, primary energy is converted to final energy, which is delivered to the end-user. In the energy end-use sub-system, final energy undergoes its final conversion into end-use energy.

An energy system can be defined in different ways by deciding where to fix the boundaries.

[4] Young, B., Gaisford, C., Henderson, J., Kemp, R., Littlefair, P., & Vijay, T. (2011). *Better product policy–policy making for energy saving in systems.* London, England: Department for Environment, Food and Rural Affairs.

[5] De Beer, J. (2013). *Potential for industrial energy-efficiency improvement in the long term (Vol. 5).* Springer Science & Business Media.

At the largest level, the boundaries can be set to include everything between primary energy and energy service, which in practice be the energy system for the country. At the lowest level, the system can be defined as a product with more than one component. A systems-approach provides the flexibility to use the definition that is most practical to apply in each individual circumstance upgrading.

Energy systems and energy services

Although the Act permits regulations to be made that prescribe MEPS for energy-using products and services, the Regulations currently only stipulate requirements for products. Neither the Act nor the Regulations define "energy-using services," and there is a wide variety of definitions used in energy research.

In a content analysis of academic peer-reviewed literature, 27 distinct definitions of "energy service" were identified, which were grouped according to themes (Table 1). 6 Broadly, these corresponded to the field in which the definitions are employed. Work related to energy efficiency tended to adopt a similar definition to the formula for energy systems, focusing on the inputs and outputs under consideration.

Theme	Definition
Useful energy/work	Energy services constituted 'useful energy' or 'useful work' – of energy being put to work in a way that is distinct from the energy use itself.
Benefit	The explicit idea that energy services entail some kind of 'benefit'.
Circular definitions	Energy services are described as the services provided by energy, without additional explanation.
End-use	An energy service is a measure of the service actually provided to ultimate consumers by their own use of energy.
Technical	Energy services are the result of conversion of energy or combining its use with technology of some kind.
Measurement of service	Energy service refers to some general or specific measure of service. For example, the definition of transport energy services is distanced travelled.
Wellbeing	Energy services are the benefits that energy carriers produce for human wellbeing.
Dominant resource	Energy service is a service where energy is a 'dominant' input in financial terms and when dedicated conversion equipment is required.

Table 1. Definitions of energy services appearing in academic literature.[6]

[6] Fell, M. J. (2017). Energy services: A conceptual review. *Energy research & social science, 27*, 129-140.

International examples

MEPS programmes are the cornerstone of energy efficiency and climate change programmes in more than 80 countries, including New Zealand's key trading partners Australia, the United States, Japan, the European Community, South Korea and Canada. Although still in its infancy, the global trend is heading towards a systems approach to MEPS.[7]

Although there are a number of energy efficiency policies that have moved beyond the individual product, they have developed largely independently of each other.

Efforts are underway in Europe to introduce standards for "extended products," which extend the boundaries of the product to include other products influencing the performance of the product. For example, the European standard EN 50598-2 defines energy efficiency indicators ("IE" and "IES") for the complete drive module (CDM) and the combination of the CDM and motor to form a "power drive system."

The EU has also signalled the importance of reducing energy consumption in the building sector. They have established a legislative framework that includes the Energy performance of buildings directive (EPBD) and the Energy efficiency directive. The Energy Performance of Buildings Directive requires all new buildings to be nearly zero-energy by the end of 2020. All new public buildings must be nearly zero-energy by 2018.

[7] Calero-Pastor, M., Mathieux, F., Brissaud, D., & Castellazzi, L. (2017). From product to system approaches in European sustainable product policies: analysis of the package concept of heating systems in buildings. *Energies, 10*(10), 1501.

Challenges

A systems approach to MEPS comes with a unique set of challenges.

Determining boundaries

The bulk of emissions and energy used in a system are invisible to end users. The value chain of products and services are large, complex and global. To increase energy efficiency, we need to be able to accurately measure and understand the efficiency of a system.

Responsibilities

A systems approach involves multiple stakeholders, often more than one manufacturer and an importer. This adds special challenges when defining the system, deciding which part of the system to act on and attributing responsibility for the final measured performance.

For example, the building industry is highly fragmented— with design decisions, construction practices, and building operations divided into distinct disciplines with little consultation among the various actors. In addition, once the building has been constructed, the interests of a building owner conflict with the building occupier. If a building did not meet the prescribed MEPS requirements, would it be the architect, engineer, builder, building-owner or tenant who contravened the Regulations?

Testing

Compliance with the MEPS programme is enforced through a check-testing programme. Traditionally, products are tested under specific laboratory conditions. Careful consideration will be needed when determining which systems can be tested and at what point in the lifecycle of the system.

Interactions

Different policies with the goal of reducing environmental impacts coexist. Increasing the energy efficiency of a system, may involve using another product that has more harmful environmental impacts.8 It will be important to determine how each proposed systems-MEPS interacts with other micro and macro environmental policies.

[8] Dalhammar, C., Machacek, E., Bundgaard, A., Zacho, K. O., & Remmen, A. (2014). *Addressing resource efficiency through the Ecodesign Directive: A review of opportunities and barriers*. Nordic Council of Ministers.

Opportunities

The addition of a complementary systems approach to MEPS would allow a major expansion of scope under the Regulations.

As outlined above, an 'energy service' and 'energy system' may be defined in the same way. Although the Act already permits regulations to be made that prescribe MEPS for energy-using services, we are proposing to explicitly allow MEPS for energy systems as part of our Regulatory Amendment Project.

A systems approach to energy efficiency policy making would complement a products approach in both the industrial/commercial and residential policy areas. With the increasing demand for higher comfort levels, buildings alone contribute to 55 per cent of energy consumption in New Zealand.[9]

In addition, a systems approach provides an appropriate vehicle to collaborate with a number of public sector agencies to put energy efficiency in the spotlight and demonstrate that it is a necessary tool for achieving the countries other, broader, personal and social outcomes.

The following discussion of products and services is not meant to be exhaustive. These examples illustrate the range of products and services that offer opportunities for improving the efficient use of energy by taking a systems-wide perspective.

Industrial/Commercial

In the past, New Zealand and Australia's energy efficiency program has primarily targeted household electrical equipment. The E3 Prioritisation Plan is now turning attention to the creation of MEPS for equipment used in the industrial sector.

Initially, the three equipment types being considered are pumps, boilers and air compressors. In New Zealand, it is estimated that pumps systems and air compressors account for approximately 19 per cent of industrial electricity use and that boilers account for approximately 64 per cent of industrial natural gas use.[10]

[9] Energy end use database

[10] Ibid.

In a prioritization of technologies and products that offer opportunities for energy efficiency improvements, the Diary, Meat, Food, Pulp, Wood, Horticulture and Wool sectors were identified as large energy users and carbon emitters. Further investigation clarified the type of technologies used in the sectors. Lights, space heating, refrigeration systems and internal combustion engines showed the most potential for energy efficiency increases.

Improving the efficiency of these sectors involves many technical actions implemented under diverse political, economic, business and managerial circumstances. Beyond individual product design, industrial energy efficiency can be improved in a number of ways:

Maintaining, refurbishing and retuning equipment to counter natural efficiency degradation and to reflect shifts in process parameters.

Retrofitting, replacing and retiring obsolete equipment, process lines and facilities to new and state of art technologies.

Using heat management to decrease heat loss and waste energy by, for example:

Proper use of insulation.

Utilization of exhausted heat and materials from one to other processes.

Improving process control, for better energy and materials efficiency and general process productivity.

Streamlining processes—eliminating processing steps and using new production concepts.

Re-using and recycling products and materials.

Increasing process productivity—decreasing product reject rates and increasing materials yields.[11]

Optimising the system can complement the efficient designs of the off-the-shelf products. For example, electric motor systems often include a number of energy using products, and it has been found that adopting a systems-approach achieves substantial efficiency improvements over a product approach.

Europe have implemented an extended product approach to their product policies. These systems are usually regulated according to the service they deliver (sanitary hot water, space heating or space cooling), the energy source they use (liquid, gas or solid fuels, electricity, etc.) or their specific features (water-based or not). In the case of pumps, while the improvement of the product alone can achieve savings of 4 per cent, the extended product approach of adding adequate speed drives could achieve 30 per cent savings and further

[11] Tanaka, K. (2011). Review of policies and measures for energy efficiency in industry sector. *Energy policy*, *39*(10), 6532-6550.

system optimisation up to 45 per cent of energy savings.12

Residential

The systems approach can also be applied to residential products and services. The residential sector accounts for around 10 per cent of CO2 emissions. A study conducted by BRANZ projected that each 1 per cent improvement in energy efficiency will result in 0.1 per cent of CO2 reduction.13

One option for defining the system is to extend existing policies covering the energy efficiency of products to include the embodied energy. Embodied energy refers to the energy associated with materials as they are transformed into products. While under-utilized, the EU's Eco design directive has a mechanism in place to regulate non-energy product inputs such as materials.14 This approach also allows MEPS to be applied to non-energy-using products, such as concrete, timber, or glass.

The prospects for improving the systems within the home are also promising. For example, while significant improvements have been made in the efficiency of individual lighting components, a systems approach offers further savings. Beyond the efficiency of the lamp, the efficiency of a residential lighting system can be improved by considering the interactions between

ballasts

the luminaires or fittings in which the lamps are placed

lighting controls

the use of natural light

how the space is used.15

Transport

The transport sector provides the largest opportunity to improve New Zealand's energy productivity and energy-related emissions profile. Transport accounts for 20 per cent of New Zealand's emissions, and it is clear that transport cannot sustainably develop along the current path.16 While reducing emissions from transport will largely rely on switching from fossil fuels to renewably generated electricity, additional interventions are

[12] Calero-Pastor, M., Mathieux, F., & Brissaud, D. (2016). Environmental assessment to support ecodesign: from products to systems: A method proposal for heating systems and application to a case study. EUR 28250 EN, doi:10.2788/165319

[13] BRANZ. (2003). Energy Use in New Zealand Households.

[14] Scott, K., Roelich, K., Owen, A., & Barrett, J. (2018). Extending European energy efficiency standards to include material use: an analysis. *Climate policy*, *18*(5), 627-641.

[15] Young, B., Gaisford, C., Henderson, J., Kemp, R., Littlefair, P., & Vijay, T. (2011). *Better product policy–policy making for energy saving in systems.* London, England: Department for Environment, Food and Rural Affairs.

[16] Interim Climate Change Committee. (2019). *Accelerated Electrification.*

required during the transition period. The most obvious approach is to limit mobility, however, the White Paper for European Transport emphasized that curbing mobility is not an option without severely compromising the economy and people's way of life.17 There are several other approaches to regulating the energy efficiency of transport services.

It is important to encourage efficiency of the diesel/petrol fleet. For example, freight shipments over short and medium distances are likely to remain reliant on trucks. In the United States, Corporate Average Fuel Economy (CAFÉ) standards set the average new vehicle fuel economy, as weighted by sales that a manufacturer's fleet must achieve. Since their implementation in 1975, the average fuel economy doubled by 2016.18

Another approach involves applying a MEPS level to the whole supply chain of freight or commercial transport operations. While harder to measure, a systems approach to MEPS would give companies more freedom and choice for how they meet the prescribed minimum levels.

The International Maritime Organization (IMO) has already taken positive steps by implementing the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). The EEDI monitors the amount of CO2 and the SEEMP can be implemented in various ways according to the ship type, cargo, and ship routes among other factors. In short, by determining the current energy consumption of the vessel, various measures can be implemented to more efficiently provide the same service. For example, one study found that the shipping sector could be more energy efficient, whilst maintaining the same transport service, by reducing the speed at sea and reducing the time in port.19

Buildings

In New Zealand, the energy efficiency of buildings is regulated under clause H1 the New Zealand Building Code (NZBC). The functional requirement is that buildings must be constructed to be energy efficient when the energy is used for heating, cooling, humidity control, ventilation, hot water, and artificial lighting. Unfortunately, many of these energy efficiency requirements are not prescribed or are under-enforced. While currently out of date and limited in scope and stringency, the H1 clause is currently under review, and may be the appropriate vehicle for introducing building-MEPS.

[17] European Commission. (2011). *Roadmap to a single European transport area - towards a competitive and resource-efficient transport system.*

[18] United States Environmental Protection Agency. (2020). *Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975.*

[19] Johnson, H., & Styhre, L. (2015). Increased energy efficiency in short sea shipping through decreased time in port. *Transportation Research Part A: Policy and Practice, 71*, 167-178.

New Zealand's commercial building stock consists of approximately 50,000 buildings of which nearly 33,000 buildings are used as offices or have retail use.20 Across all commercial buildings, total electricity use is approximately 6,370 GWh/yr.21

There is an opportunity to increase the energy efficiency of the 1.2 million square metres of property owned or leased by the government. Currently, the government requires any new building developed for government office accommodation to be measured for a NABERSNZ energy efficiency rating, targeting a four-star rating. Fit-for-purpose MEPS levels could be implemented for schools, hospitals, libraries, military facilities, Corrections facilities, and buildings used for government administration. Depending on the chosen system boundaries, this could be implemented via Government policy or through regulation.

New Zealand's residential building stock, of approximately 1.8 million units, offers the most opportunities in the building sector. One of the lessons from the E3 programme is that it is difficult to tailor product requirements for multiple climates, let alone specific building requirements. A building in Invercargill provides a different function from a building in Darwin.

There are several design areas that can affect the energy efficiency of a building:

Measures concerning the whole building.

The construction parts of the envelope (roof, wall, ceiling and floor).

Windows and shading.

HVAC systems.

Appliances and lighting.22

Applying a MEPS level to a whole building provides flexibility for building owners to fit the design to the requirements of the environment.

[20] Isaacs, N P., & Hills, A. 2014. Understanding the New Zealand Non-Domestic Building Stock. *Building Research & Information*, *42* (1). 95–108

[21] BRANZ. (2014). *Building Energy End-Use Study.*

[22] De Boeck, L., Verbeke, S., Audenaert, A., & De Mesmaeker, L. (2015). Improving the energy performance of residential buildings: A literature review. *Renewable and Sustainable Energy Reviews*, *52*, 960-975.

Conclusion

The prospects for applying a systems approach are promising. Although still in its infancy, the global trend is heading towards a systems approach to MEPS and energy efficiency policy more broadly.

From a systems perspective, the energy use of energy-using services is the unexploited economic potential of energy efficiency. According to APEC, the services sector – covering activities such as telecommunications, e-commerce, transportation, finance and banking, engineering, construction, legal, healthcare and education services - accounts for around 70 per cent of the GDP of New Zealand.[23]

The IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E) is investigating energy-using systems. This programme will help illuminate the full potential of a systems approach to MEPS.

[23] APEC. (2016). *APEC Services Competitiveness Roadmap Implementation Plan (2016 – 2025).*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