Willms & Shier | Environment Aboriginal Energy Law

Direct Dial: 416 862 4830
File: 6706

By Electronic Mail & RESS Filing

July 27, 2015

Ontario Energy Board
P.O. Box. 2319
2300 Yonge Street, 27th Floor
Toronto, ON M4P 1E4

Attention: Kristen Walli, Board Secretary

Dear Ms. Walli:

Re: Ontario Sustainable Energy Association's (OSEA) Evidence
Board File No. EB-2015-0029/EB-2015-0049

Please find enclosed the evidence of Chris Young on behalf of OSEA in the above noted proceeding. A copy of Mr. Young's curriculum vitae, an executed Acknowledgement of Expert's Duty form and documents cited by Mr. Young are also enclosed.

Yours truly,

J. Vince

Joanna Vince

Encl.

cc. Nicole Risse, Executive Director, OSEA
Intervenors

Document #: 875735

ONTARIO ENERGY BOARD

IN THE MATTER OF the *Ontario Energy Board Act, 1998*, S.O. 1998, c. 15 (Schedule B).

IN THE MATTER OF an Application by Enbridge Gas Distribution and Union Gas Inc. pursuant to Section 36(1) of the *Ontario Energy Board Act, 1998*, for an Order or Orders approving their Demand Side Management Plan for 2015-2020

EVIDENCE OF CHRIS YOUNG ON BEHALF OF ONTARIO SUSTAINABLE ENERGY ASSOCIATION ("OSEA")

July 27, 2015

I. QUALIFICATIONS

1 I am Chris Young of Ottawa, Ontario. I am a co-founder of Stoked Power Generation, which is developing innovative Combined Heat and Power ("CHP") and energy storage technologies for the global marketplace.

2 I have over 11 years of experience in energy management and environmental services. Over the past three years I have worked on the development and implementation of biogas and CHP projects in Ontario. I was formerly the Managing Director of Enfinity Canada, where I initiated and lead the market entry of an European renewable energy company into the Canadian market. I lead the acquisition and development of several renewable energy projects, including solar and wind farms. I was an invited speaker to the Senate of Canada

Standing Committee on Energy, the Environment, and Natural Resources, where I spoke on solar power initiatives in Canada and the challenges faced by the renewable energy sector.

3 A copy of my curriculum vitae is attached hereto and marked as **Exhibit "A"**.

II. SCOPE OF WORK

4 I have been asked by OSEA to provide my expert opinion on sustainable energy opportunities that natural gas utilities can incorporate into their Demand Side Management Plans ("DSM Plans") and address some of the barriers that prevent action on conservation and greenhouse gas emission reduction.

5 I have reviewed the applications filed respectively by Enbridge Gas Distribution ("Enbridge") and Union Gas Inc. ("Union") on April 1, 2015 to the Ontario Energy Board ("Board") for their Multi-Year Demand Side Management Plan for 2015 to 2020.

6 A copy of the acknowledgement of my expert's duty is attached hereto and marked as **Exhibit "B"**.

III. BACKGROUND - POLICY AND LEGISLATIVE FRAMEWORK

7 On May 14, 2009, the Province of Ontario enacted the *Green Energy and Green Economy Act, 2009*. Through the *Green Energy and Green Economy Act, 2009*, the Province of Ontario established a policy and legislative framework for energy conservation and environmental protection particularly with respect to greenhouse gas emissions.

8 The *Green Energy and Green Economy Act, 2009* was developed through discussions with key stakeholders, such as the Green Energy Act Alliance, who envisioned the development of a sustainable energy economy.

> **Green Energy Act Alliance, *A Vision of a Greener Energy System for Ontario*, attached hereto and marked as Exhibit "C".**
>
> **Green Energy Act Alliance, *Rationale for the Green Energy Act*, attached hereto and marked as Exhibit "D".**

9 Sustainable energy approaches are critical to both energy conservation and environmental protection. Despite progress in specific areas, significant programmatic, institutional and regulatory processes and practices within many key organizations in the energy sector have limited progress on achieving the provincial targets on these two matters. With respect to greenhouse gas emissions, Ontario's challenge is moving beyond phasing out coal and reducing the carbon content of applications such as heating and transportation.

10 The Environmental Commissioner of Ontario in his 2015 annual greenhouse gas progress report to the Legislative Assembly of Ontario stated:

> *With Ontario's emissions projected to be lower in 2014 due to the closure of its final coal-powered electricity plant, Ontario looks likely to meet its 2014 target (which is also 171 Mt)… the last several years have witnessed a significant decline from the peaks experienced roughly between 2000 and 2005, when emissions from coal-fired electricity generation were highest.*
>
> *However, meeting the 2020 target will prove more difficult. Ontario faces a large gap (19 Mt - equal to 11 per cent of its total current GHG emissions) between the province's projected 2020 emissions based on current policies and trends and the 2020 target. Without new policy initiatives, the majority of Ontario's emissions reductions (78 per cent in 2020) will have come from the single initiative of phasing out the use of coal in the electricity sector. <u>The government's biggest climate change challenge going forward is to achieve sufficient GHG reductions beyond the electricity sector to meet its 2020 target</u>.* [emphasis added]

Environmental Commissioner of Ontario, *Feeling the Heat: Greenhouse Gas Progress Report 2015*, online: <http://www.eco.on.ca/uploads/Reports-GHG/2015/2015%20GHG.pdf>.

11 While the *Green Energy and Green Economy Act* had some elements that addressed natural gas, additional legislative tools and Orders in Council were required to amend the undertakings for the natural gas utilities.

12 On September 8, 2009, the Lieutenant Governor approved and ordered Order in Council No. 1540/2009, enclosing a Ministerial Directive from the Ministry of Energy and Infrastructure. The 2009 Ministerial Directive authorizes Enbridge and Union to directly own and operate renewable energy electricity generation facilities with a capacity of ten (10) megawatts or less, facilities that generate heat and electricity from a single source, or facilities that store energy. This included solar-thermal water and ground-source heat pumps. The purpose of the 2009 Ministerial Directive is to reduce the use of natural gas and electricity.

Ministerial Directive O.C. 1540/2009 dated September 8, 2009, attached hereto and marked as Exhibit "E" [2009 Ministerial Directive].

13 On March 26, 2014, the Lieutenant Governor approved and ordered Order in Council No. 467/2014, enclosing a Ministerial Directive from the Ministry of Energy. The 2014 Ministerial Directive directs the Board to take action to promote electricity conservation and demand management ("CDM") and natural gas DSM. The 2014 Ministerial Directive requires the Board to create a policy framework that includes the cooperation and coordination between electricity distributors and gas distributors when planning and implementing the CDM and DSM plans, respectively.

Ministerial Directive O.C. 467/2014 dated March 26, 2014, attached hereto and marked as Exhibit "F" [2014 Ministerial Directive].

IV. <u>SUSTAINABLE ENERGY OPPORTUNITIES RELATED TO INTEGRATED DSM AND CDM</u>

14 The 2014 Ministerial Directive requiring gas and electric distribution companies to collaborate more closely should be recognized as an opportunity for a broader range of activities for both gas DSM and electric CDM. This includes a fuller realization of the vision enunciated by the Green Energy Act Alliance and the *Green Energy and Green Economy Act* and implementation of sustainable energy measures, such as high efficiency CHP, ground source heat pumps and solar thermal water heating.

15 The following are examples of opportunities that Enbridge and Union can implement in their DSM Plans pursuant to a broader energy systems approach to conservation and related sustainable energy applications.

A. COMBINING AVOIDED COSTS FOR NATURAL GAS AND ELECTRICITY

16 The current approach of regulating natural gas and electric utilities independently leads to overlooked efficiencies. Currently, Ontario's supply of electricity is dominated by large central power plants that have relatively low overall efficiency rates, which results in a large waste of heat energy.

17 Combining the avoided costs for both electricity and natural gas, plus using the prescribed 15% adder for non-energy benefits would allow a broader range of technologies, measures and applications than gas only analyses or electric only analyses.

Compared to single-fuel programs, combined natural gas and electric energy efficiency programs often deliver additional energy *and dollar savings at lower cost to utilities and consumers. They also enhance customer satisfaction. Many leading dual-fuel programs demonstrate these benefits. Energy efficiency programs that include both gas and electricity measures have many benefits that are not available to standalone programs. Chief among these are the increased savings that result from programs and portfolios of larger size and greater resources. A gas-only program (or a particular gas measure or project) may not be cost effective enough to meet applicable benefit-cost (BC) test requirements, but when it is combined with electric measures as part of a dual-fuel efficiency program, the project as a whole has a high enough BC ratio to pass screening tests. Home weatherization programs are an obvious example.*

American Council for an Energy-Efficient Economy, *Successful Practices in Combined Gas and Electric Utility Energy Efficiency Programs*, dated August 2014.

18 Water savings have played a major role in natural gas DSM since 1995. The interconnection between energy and water is increasingly viewed as a critical element of conservation and sustainability.

Water and energy are linked, intersecting at both the supply side (electric generation and water/wastewater facilities) and the end-use side (residential, commercial, industrial, and agriculture sectors). This linkage is commonly called the energy-water nexus. On the supply side, this intersection is apparent in the massive amounts of water needed to produce electricity and the while large amounts of energy required to treat, process, and transport water. On the end-use side, energy and water are connected in our homes, businesses, and industrial facilities. The water-energy linkage means that end-use efficiency programs that save water will also save energy and vice versa.

American Council for an Energy-Efficient Economy, *Watts in a Drop of Water: Savings at the Water-Energy Nexus*, dated November 2014.

B. NET ZERO BUILDINGS

19 While both Enbridge and Union are pursuing opportunities in new construction, their involvement in the new construction market could be much more robust with a full market transformation approach rather than a hybrid of resource acquisition programs and market transformation.

20 Traditionally, the programs have used a process to build better than code by a fixed per cent while no research has been done to understand how Ontario's Building Code actually performs with the current patchwork of compliance at the municipal level, where traditional code compliance has focused on safety, not energy. The potential for working with the local electric distribution utilities is further limited given their short term focus on saving kWh as embedded in their targets. Without strong policy or regulatory direction to avoid lost opportunities, Ontario will not be able to address all of the new construction opportunities.

> *Approximately one third of Canada's GHG emissions are attributed to building energy consumption. Buildings also account for about 53% of Canada's electricity consumption. They are largely responsible for the peaks in electricity demand associated with space heating, cooling, lighting and appliances. These peaks, if not reduced and shifted in time, will impose additional requirements to build new power plants. Without a major transformation in the way we design, build, and operate buildings, Canada cannot expect to meet its goals for reductions in greenhouse gas (GHG) emissions and for clean air in its cities. Mechanisms that allow the building to act as a net energy generating system and also shift peak demand can provide the basis for this transformation. At the same time, a comparison of the Canadian construction industry with that in other industrialized nations, points out the urgent need for Canadian innovations. This convergence of the need for innovation and the requirement for drastic reductions in energy use and GHG emissions provides a unique opportunity to transform the way we conceive buildings and their energy systems. This Network is a vital step along the way to achieving these goals. It links researchers from academia, industry and government in a united effort to develop the technologically advanced smart net-zero energy buildings (NZEBs) of the future. A net-zero energy building is defined as one that, in an average year, produces as much energy (electrical plus thermal) from renewable energy sources as it consumes.*
>
> **NSERC Smart Net-Zero Energy Buildings Strategic Research Network, online: <http://www.solarbuildings.ca/documents/FINAL%20SNEBRN_executive%20summary%20extended%20-%20REVISED%20JULY%202014.pdf>.**

C. PERFORMANCE BASED CONSERVATION – ACHIEVING THE ADDITIONAL DSM SAVINGS

21 Performance based conservation begins with identifying high energy intensity buildings through benchmarking and then works systematically towards identifying and fixing the particular inefficiencies causing the high use in each building covering gas, electricity, district energy and water. The nature of the inefficiencies runs the range of errors in design and construction, through equipment deterioration over time, to changes in use and operation of the building, and poor performance of controls and automation systems. It is the compound effect of these problems that leads to energy use levels in some buildings which is 3 to 5 times what is needed and already achieved by comparable, more efficient buildings. Fixing these problems requires a systematic methodology. The work involved in equipment repairs and replacement, right-sizing and rebalancing, refurbishment and re-programming, typically provides relatively short payback periods.

D. FUEL USE EFFICIENCY

22 An overall energy systems perspective means that improving the efficiency of the generation of electricity from natural gas from the typical efficiency of less than 40 per cent to a CHP efficiency well in excess of 90 per cent is conservation of energy. Related avoided transmission and distribution losses also represent conservation.

> *By generating much more useful energy from a single fuel input, CHP offers tremendous economic and environmental benefits to individual system owners, the local grid and society as a whole.*
>
> **Anna Chittum and Kate Farley, *Utilities and the CHP Value Proposition*, dated July 19, 2013.**

23 While efficiencies of CHP systems are dependent on the end use activity, the typical efficiency of conventional energy systems is relatively constant. For conventional thermal power plants like nuclear, coal or gas, an estimated 55-65% of energy generated is in the form of waste heat from steam turbines that is then discharged into the environment. The result is an overall energy efficiency rating which is much lower than that of a well-designed CHP system driven by heat utilization requirements. An illustration of the typical energy losses in conventional and renewable energy sources is attached hereto and marked as **Exhibit "G"**. A table setting out the characteristics of CHP plants is attached hereto and marked as **Exhibit "H"**.

24 Regulatory practices in Ontario have not been revised to reflect the broader societal benefits of CHP.

> *While some of the benefits of CHP confer to individual CHP-using facilities, most of them are public benefits conferring to society and the local grid. Individual facilities cannot fully enjoy system wide benefits but utilities can. Utilities are best positioned to help monetize the public benefits provide by CHP, and in turn convey the benefits to all of their customers.*
>
> **Anna Chittum and Kate Farley, *Utilities and the CHP Value Proposition*, dated July 19, 2013.**

25 While the principal of CHP is not new, its deployment in North America has been limited due to the focus on overwhelming emphasis on large central power plants.

26 Although large central power plants dominate today's infrastructure, this was not always the case as historically factories and communities were at one time responsible for their own electricity generation needs. The advent of new technologies like wind and solar power coupled with innovations in CHP systems

will bring a return to localized energy generation. In the case of CHP, significant grid reliability benefits exist beyond the reduction in waste heat. A comparison of energy-efficiency of a standard power plant versus a district energy/CHP plant is attached hereto and marked as **Exhibit "I"**.

27 From my analysis of the electricity generation mix of the Ontario electricity grid and the energy consumption profiles of Ontario's residential and commercial building stock, it is estimated that a shift away from large central power plants to on-site CHP could save approximately 63.3 TWh/yr of electricity and reduce electricity bills by as much as $12.5 billion dollars per year for Ontarians.

> **C. Young, Green Building, infrastructurecanada.ca, *Putting Conservation First Means Big Savings For Ontarians*, online: <http://cuksbn.org/wp-content/uploads/Green-Building-in-Canada.pdf> at page 2.**

E. DISTRICT ENERGY

28 A broader use of thermal energy distribution (district energy) and shared renewable energy (both thermal and electrical) amongst clusters of buildings improves efficiency and conserves energy.

> *Utilities are well versed in making long-term investments, and they are well positioned to encourage strategically sited CHP that can provide major benefits to the grid. Utilities have existing relationships with most of the customers that would be good candidates for CHP and they can enjoy many of the benefits of CHP much more directly than individual CHP users might be able. Utilities also have the ability to use ratepayer funds to support projects that will provide system wide benefits and their CHP programs can help accelerate market adoption of the technology, all while providing economic and environmental benefits to all system users.*
>
> **Anna Chittum and Kate Farley, *Utilities and the CHP Value Proposition*, dated July 19, 2013.**

F. GROUND SOURCE HEAT PUMPS

29 Changes to the natural gas utilities' mandates in 2009 made eminent sense. For decades the companies have put pipes in the ground to transport a fossil fuel which, although less polluting than coal, remains a cause of greenhouse gas emissions. Both ground source heat pumps and solar thermal water heating, the two major uses of natural gas in buildings, use pipes to transport renewable energy that are not intermittent. Both applications represent a long term business opportunity in a carbon constrained world.

30 The use of ground source heat pumps can make more efficient use of electricity for cooling and reduce the peak demand for natural gas in the winter with greenhouse gas emissions reductions in both seasons. Subdivision scale systems or systems serving more than one building in a complex will enable unit cost reductions from scope and scale.

> *A ground-source heat pump uses the earth or ground water or both as the sources of heat in the winter, and as the "sink" for heat removed from the home in the summer. For this reason, ground-source heat pump systems have come to be known as earth-energy systems (EESs). Heat is removed from the earth by using a liquid, such as ground water or an antifreeze solution; the liquid's temperature is raised by the heat pump; and the heat is transferred to indoor air. During summer months, the process is reversed: heat is taken from indoor air and transferred to the earth by the ground water or antifreeze solution. A direct-expansion (DX) earth-energy system uses refrigerant in the ground-heat exchanger, instead of an antifreeze solution. Earth-energy systems can be used with forced-air and hydronic heating systems. They can also be designed and installed to provide heating only, heating with "passive" cooling, or heating with "active" cooling. Heating-only systems do not provide cooling. Passive-cooling systems provide cooling by pumping cool water or antifreeze through the system without using the heat pump to assist the process. Active cooling is provided as described below, in "The Cooling Cycle." As with air-source heat pumps, earth-energy systems are available with widely*

varying efficiency ratings. Earth-energy systems intended for ground-water or open-system applications have heating COP ratings ranging from 3.6 to 5.2, and cooling EER ratings between 16.2 and 31.1. Those intended for closed-loop applications have heating COP ratings between 3.1 and 4.9, while EER ratings range from 13.4 to 25.8. The minimum efficiency in each range is regulated in the same jurisdictions as the air-source equipment. There has been a dramatic improvement in the efficiency of earth-energy systems. Today, the same new developments in compressors, motors and controls that are available to air-source heat pump manufacturers are resulting in higher levels of efficiency for earth-energy systems.

Natural Resources Canada, *Ground-Source Heat Pumps (Earth Energy Systems),* dated April 15, 2014, online: <http://www.nrcan.gc.ca/energy/publications/efficiency/heating-heat-pump/6833>.

G. ENERGY (INCLUDING THERMAL) STORAGE

31 To date, Ontario's approach to energy storage has been centered on electricity. In fact an overall energy systems approach combining thermal and storage and electricity storage would yield greater benefits. Such a broader approach is common in Europe. An illustration of potential energy storage integration opportunities is attached hereto and marked as **Exhibit "J"**.

Energy storage technologies can support energy security and climate change goals by providing valuable services in developed and developing energy systems. A systems approach to energy system design will lead to more integrated and optimised energy systems. Energy storage technologies can help to better integrate our electricity and heat systems and can play a crucial role in energy system decarbonisation by: improving energy system resource use efficiency; helping to integrate higher levels of variable renewable resources and end-use sector electrification; supporting greater production of energy where it is consumed; increasing energy access and improving electricity grid stability, flexibility, reliability and resilience.

International Energy Agency, *Technology Roadmap – Energy Storage*, online: <http://www.iea.org/publications/freepublications/publication/technologyroadmapenergystorage.pdf>.

32 The International Energy Agency Energy Storage Roadmap outlines a variety of storage technologies which are at various stages of commercial deployment. The use of energy storage technologies is a widely acknowledged tool to facilitate broad based deployment of renewable energy systems. A copy of the IEA Energy Storage Roadmap is attached hereto and marked as **Exhibit "K"**.

33 One example of a renewable energy storage approach that is closely linked to CHP and natural gas which could be adopted here in Ontario as a DSM initiative is the injection of Bio-Methane into the natural gas network. This is an activity that produces green gas from agricultural activities and food waste to offset fossil fuel consumption. Integration of Bio-Methane into traditional natural gas networks is being pursued in the UK and other jurisdictions in Europe where over 160 Bio-Methane plants currently feed renewable gas into the natural gas network.

> **UK Government, Department of Energy & Climate Change, *RHI Biomethan Injection to Grid Tariff Review*, online: <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/384202/Biomethane_Tariff_Review_-_Government_Response_-_December_2014.pdf>.**
>
> **S. Strauch, J. Krassowski, A. Singhal, *Biomethane Guide for Decision Makers – Policy guide on biogas injection into the natural gas grid* dated September 2013, online: <http://www.greengasgrids.eu/fileadmin/greengas/media/Downloads/Documentation_from_the_GreenGasGrids_project/Biomethane_Guide_for_Decision_Makers.pdf>.**

H. DENMARK – REAL WORLD EXAMPLE

34 Other jurisdictions, such as Denmark, provide proven examples of integrated energy policy and regulation.

35 In 1979, the Danish government introduced the *Danish Heat Supply Act*. The act is similar to Ontario's *Green Energy Act* and was intended to assist Denmark

meet its Energy Efficiency, Renewable Energy and Climate Change policy targets and transition to 50% wind power by 2020 and 100% renewables by 2050.

> **Denmark Official Website, *Wind Energy*, online: <http://denmark.dk/en/green-living/wind-energy/>.**

36 The policy affects Buildings, Residential Appliances, Space heating, Commercial/Industrial Equipment, Heating Ventilation and Air Conditioning (HVAC), Energy Utilities, Electricity, Generation, Energy Utilities, Heating (including district heating), multiple Renewable Energy Sources, CHP, District Heating and Cooling and other Multi-sectoral Policy.

> *The Heat Supply Act from 1979 (revised extensively in 1990, 2000 and 2005) empowers the Minister for Energy to ban the use of electric heating in new buildings located within a district heating or natural gas supply network. The Minister made use of this empowerment in 1988. In 1994 the Heat Supply Act was revised to extend the Ministers empowerment to also include a ban on conversion to electric heating in existing buildings. The Minister made use of this extended empowerment in the same year. This measure has reduced the number of electrically heated homes by over 9000. In 1994 6.5 % of the Danish homes were electrically heated, while in 2008 only 5.3 % were. Other provisions in the Heat Supply Act include: obligatory connection to the district heating or natural gas supply network, the principle of co-generated heat and electricity and the principle for heat pricing. The possibility to ensure that all buildings in a given area connect to the district heating or natural gas network, has increased the coverage of district heating considerably. Only about 650,000 of Denmark's 2.7 million households have an individual heat supply. About 80% of district heating is co-produced with electricity, due to the Heat Supply Acts provision, that plants larger than 1 MW have to be operated as combined heating plants. As a result, Denmark has the most extensive co-generated heat and electricity system in EU, with more than half of all Danish electricity co-generated with heat. The principle for heat pricing stipulates that heat supplies must be priced according to actual costs on a non-profit basis. To increase the utilization of renewable energy resources and industrial surplus heat, heat based on these resources can though be sold with a*

certain profit within boundaries, set by the Danish Energy Regulatory Authority

International Energy Agency, *Heat Supply Act*, online: <http://www.iea.org/policiesandmeasures/pams/denmark/name-21778-en.php>.

37 Since its introduction in 1979 the *Heat Supply Act* has spurred the development of many smaller renewable and fossil fuel CHP plants throughout Denmark. Major manufacturers (the automotive sector) as well as distributed district heating companies utilize the heat.

A. Andresen et al, *Overview of the Danish Power system and RES integration* dated July 2013 online <http://www.store-project.eu/documents/target-country-results/en_GB/energy-needs-in-denmark-executive-summary> at page 13.

38 These distributed CHP plants are a form of energy “storage” providing demand management services akin to other bulk energy storage technologies. CHP has enabled Denmark’s grid operators to integrate large amounts of fluctuating production from wind turbines by ramping up when demand outreaches renewables supply while absorbing surplus power using electric boilers to create valuable heat that can be used for hot water, heating, manufacturing as well as absorbed using heat pumps and thermal stores for use later. By valuing both power and heat in an integrated way, value can be captured and created for the system as well as for consumers. In 2014 more than 41% of Denmark’s demand was met by wind power because of the integration of thermal and electrical networks.

39 Denmark’s integrated energy transition has resulted in a significant shift in fuel consumption for electricity and heating. The Danish Energy Agency’s baseline scenario highlights this shift and is attached hereto and marked as **Exhibit “L”**.

40 The integration of thermal and power systems in Denmark has led to an important shift in the supply mix that is consumed with a significant reduction in power from large centralized facilities as well as a reduction in the consumption of combustible fuel overall and fossil fuels. Charts showing power consumption and generation and fuel consumption in Denmark are attached hereto and marked as **Exhibit "M"**.

41 The reduction in combustible fuel use, better technology and the use of cleaner fuels in the CHP systems has resulted in a significant reduction of emissions of CO_2 (41%), SO_2 (97%) and NO_X (84%) in Denmark. A chart showing the emissions in Denmark between 1990 and 2010 is attached hereto and marked as **Exhibit "N"**.

42 Denmark's 2.7 million households are benefitting from this shift directly. About 650,000 of Denmark's 2.7 million households have an individual heat supply with the remainder receiving space heating and hot water from district energy systems. Those connected to the district hot water systems pay an average cost of just 3% of the average household income for these services compared to 22% in Canada.

> **Danish Energy Agency, *Basic facts on Heat Supply in Denmark*, online: <http://www.ens.dk/en/supply/heat-supply-denmark/basic-facts-heat-supply-denmark>.**
>
> **Danish Energy Agency, *The Danish Energy Model – Innovative, Efficient and Sustainable*, online: <http://www.ens.dk/sites/ens.dk/files/dokumenter/publikationer/downloads/dk_model_150422.pdf> at page 13.**
>
> **C. Aguilar, D.J. White, and D. L. Ryan, *Domestic Water Heating and Water Heater Energy Consumption in Canada*, dated April 2005, online: <http://sedc-coalition.eu/wp-content/uploads/2011/07/CREEDAC-Canadian-Residential-Hot-Water-Apr-2005.pdf>.**

43 From an emissions perspective the Danes integrated approach holds significant insights into how we could lower our heating emissions over time while reducing the overall cost to ratepayers through a distributed approach to energy generation and use. A summary of Ontario and Denmark's comparable Green House Gas Emissions is attached hereto and marked as **Exhibit "O"**.

44 Ontario CHP and district energy services providers such as Markham District Energy and Toronto's Enwave could provide these types of services immediately while new proponents could offer similar services if the regulatory environment was further strengthened in Ontario.

Document #: 872316

Exhibit “A”

Chris Young

916 Hamlet Rd. Ottawa, Ontario K1G 1R5 P: 613.322.2472 email: norsunenergy@me.com

Highlights

Strong market entry skills focused on conceptualizing and implementing business solutions through improved processes and innovative technology.

- Over 11 years experience developing and delivering Energy Management and Environmental Services including successful Financing and Construction of a 33.6MW, $145 million power project sold to a publicly listed company
- Demonstrated Leadership on Energy Policy Matters – invited speaker to The Senate of Canada Standing Committee on Energy the Environment and Natural Resources
- Solid understanding of Project Finance and Business Case Development with non-recourse finance
- Built a strong sales and technical team to originate and assess over 300MW of Solar and Wind projects
- Participated in the launch of two licensed hazardous waste treatment facilities specializing in the treatment of Mercury and PCB containing lighting industry. Helping to advance environmental regulations across Canada
- Developed a first of it's kind National Product Stewardship program for mercury contaminated lighting waste
- Former Board Member, Ontario Sustainable Energy Association policy advisory on climate change issues
- Positioned Stoked Power Generation to become selected to join Sustainable Development Technology Canada – Natural Gas Technology Incubator for the development of small scale Combined Heat and Power technology

Skills

A demonstrated ability to realize Multi Million Dollar business concepts in complex Government Regulated environments and a challenging global financial market.

Market Definition - Identification of new market opportunities technology and processes including product validation with early adopters.

Competitive Analysis – Examination of external firms in direct competition and, broader technical developments which can impact on success.

Product Positioning – Worked with potential clients and the CTO to define functional requirements incorporated into the product development plan.

Pricing and Business modeling – Participated in the development of a number of business plans. Contributed to, market definition and sales forecasts.

Market Research – Primary and secondary market research techniques for competitive intelligence and customer analysis.

Strategic Sales – Identification of key accounts that can lead to significant growth through an industry vertical.

Strong Network of energy related colleagues that span Europe, North America and Asian.

Employment History

November 2010 – 2014	**Volunteer Board Member – Ontario Sustainable Energy Association** Assisting non-profit organization in policy initiatives to advance renewable energy with various government stakeholders.
September 2012 – Present	**Business Development – Biogas and Combined Heat and Power** Initial development of anaerobic digestion projects identified a significant technical challenge with prime mover technologies available in the North American market. To address the shortcomings of existing small scale CHP technology, partnered with **Stoked Power Generation** to commercialize innovative Combined Heat and Power technology.
January 2012 – September 2012	**Consultant – Green Energy Finance Company** Advised an international merchant banker on dynamics of utility scale PV market as they position to raise funding for project acquisition.
January 2008 – November 2011	**Managing Director – Enfinity Canada** Initiated and lead the market entry of one of Europe's leading renewable energy companies into the Canadian Market. Originated, and lead the successful acquisition of Solaris Energy Partners, a 244 acre, 33.6MWp Solar farm in Eastern Ontario. Guided Solaris through remaining permitting requirements, including completion of Ontario Municipal Board hearings and Hydro One Interconnection requirements. Worked closely with Engineering and Finance teams to advance Solaris from concept through design, procurement and construction, to a $140 million exit to a TSE listed company. In addition to the Solaris project, established a business development program that created a pipeline of rooftop and groundmount projects that will be valued in excess of $500Million once constructed. Worked collaboration with an international team of technical specialists, to lead due diligence review on a number of wind development opportunities representing potential installed capacity of approximately 900MW located across Canada. Participated on management board of Enfinity America's Group - Strong understanding of Non-Recourse Finance and capital structures - Ability to convey complex technical issues to political decision makers - **Broad understanding of electricity markets in European and North American markets** - Ability to work with colleagues and vendors across many countries - Execution of an EPC strategy for construction of 33MW Solar Facility - Definition of Value Proposition and Commercial terms on competitive PPA's
December 2006 – November 2007	**Vice-President of Solar Farm Development, Solstice Solar Energy** Secured early stage seed investment from two of Canada's leading Internet Entrepreneurs to launch a Solar Development Company

Collaborated on the development of the business plan and developed a marketing program targeted at potential community partners.

Conducted extensive market research into the Ontario Renewable Energy Standard Offer Program including; detailed review with legal and financial advisors.

Development of detailed Solar Resource assessments using a variety of Solar Energy Modeling tools including RETSCREEN and PVWatts for various locations in Ontario.

Lead discussions with equipment manufacturers regarding equipment supply for utility scale solar farm developments.

September 2000 - January 2006 — **Non- Environment/Power Related** Business Development

Various software related startup companies.

May 1993 - September 1999 — **Business Development, Material Resource Recovery**

Secured lead customers to anchor the construction of a hazardous waste incinerator to treat hazardous waste, including Poly Chlorinated Biphenols.

Contributed to plans and procedures to meet due diligence of clients that included The Government of Canada and some of Canada's largest Financial Institutions.

Assisted in preparing facts based response to community concerns and designed a community engagement process that satisfied the needs of

May 1993 - September 1999 — **Business Development, RLF Canada,**

Secured several noted, "Blue Chip" clients as lead customers for an innovative treatment facility for mercury contaminated lighting waste. Amongst others: GE Canada, Royal Bank of Canada, BCE Place, and Public Works Government Services Canada

Succeeded in raising awareness of environmental liabilities from mercury contaminated lighting waste amongst Municipal landfill operators and Government Regulators.

Obtained a "Certificate of Approval" from the Ontario Ministry of Environment to exempt the reverse distribution and recycling of Fluorescent lights from Regulation 347 of the Environmental Protection act.

Developed a product stewardship program with Industry partners that enabled the recycling of lighting waste for building owners on a national basis without the need for Hazardous Waste Permits

Education: University of Ottawa, Bachelor of Social Science 1993

Relevant Courses: Environmental Impact Assessment, Natural Resource Management, Geography of Economic Systems, Business, Marketing, Promotional Management, Business Law, Services Marketing.

Exhibit “B”

FORM A

Proceeding:

ACKNOWLEDGMENT OF EXPERT'S DUTY

1. My name is Christopher Young ....(*name)*. I live at 916 Hamlet Road .... (*city)*, in the Ottawa .... (*province/state*) of Ontario ....

2. I have been engaged by or on behalf of OSEA .... (*name of party/parties)* to provide evidence in relation to the above-noted proceeding before the Ontario Energy Board.

3. I acknowledge that it is my duty to provide evidence in relation to this proceeding as follows:

   (a) to provide opinion evidence that is fair, objective and non-partisan;

   (b) to provide opinion evidence that is related only to matters that are within my area of expertise; and

   (c) to provide such additional assistance as the Board may reasonably require, to determine a matter in issue.

4. I acknowledge that the duty referred to above prevails over any obligation which I may owe to any party by whom or on whose behalf I am engaged.

Date July 23rd, 2015 ....

Signature

Exhibit “C”

401 Richmond Street West, Suite 401
Toronto, Ontario M5V 3A8
(t) 416.977.4441 * (f) 416.977.2157
www.greenenergyact.ca

Green Energy Act Alliance

A Vision of a Greener Energy System for Ontario

Energy
From each and for all
Making it green while using less

On September 16, over 100 people gathered to envision a greener Ontario. The group was diverse: First Nations, farmers, advocates and practioners, current and retired employees of local distribution companies and municipalities, civil servants, lawyers, business leaders and a broad representation of nongovernmental organizations. As the Premier likes to say, "Together we are better".
Together they imagined what a green Ontario might look like in 2020:

- Ontario's economy is sound, largely due to successful, profitable green enterprises.
- Cities and communities are livable.
- The cities are dark at night.
- Cities are quiet, transit and vehicles are electric sidewalks are wide, bicycles are ubiquitous.
- The air is clear, clean and invigorating – no smog or particulates polluting the air.
- Energy conservation is neither a question nor a concern – it is a lifestyle.
- People are engaging in recreation and leisure, enjoying healthy and clean food, air, water and outdoors.
- Sustainability is the foundation of society.
- Food production is local. Parking lots have become community gardens.
- All forms of pollution are taxed at its true cost to society.
- Our environment has turned around. The Arctic ice caps have stopped receding; people are no longer dying because of the air they breathe and the lakes, rivers and forests are again alive with wildlife.
- Our homes and building are net generators of electricity.
- Ontario natural habitats are protected, accessible and respected by all.
- Energy is produced where it is used.
- It is easy for everyone to generate green power and to connect it to the grid – no more barriers.
- All energy is from low or no impact sources – renewable or clean
- Renewable energy services are main stream, like mobile phones.
- We have a decentralized electricity system empowering and benefitting local communities, First Nations and Ontario's farmers as well as the system as a whole.
- Local distribution companies develop sustainable infrastructure, implement conservation and facilitate renewable and distributed generation.
- Last remnants of nuclear power are 2 units at Darlington and Bruce A, which are all scheduled for phase out and decommissioning by 2030.
- Oil is not longer the fuel of choice.
- Ontario public policy drives efficient use of green energy
- Ontario is are a leader in green job creation, green products and green planning and regulation

- All politicians embrace and demonstrate their commitment to sustainability. They have finally realized that "green change" is not as risky as they thought.

The Green Economy is Thriving

- Ontario's economy is driven by the green industry resulting in a substantial number of green collar workers. Green industries are the leading source of employment in Ontario. Investment policies and economic development strategies reflect sustainability and community goals.
- Ontario has a workforce with new and retrained workers that replace the manufacturing jobs that have been lost. Workers have been trained and re-skilled to install and maintain renewable energy and distributed generation.
- First Nations are included in a meaningful way in Ontario's sustainable and renewable energy industry
- Optimization of efficiencies in food production, renewable energy production, and re-use of waste support rural economic development.
- Improved energy efficiency in industry has increased our energy productivity and economic competitiveness dramatically.

The Conservation Culture is Green

- In order to protect Ontario's natural habitats and reduce our province's environmental impact, our culture of conservation is embraced by all energy consumers. The conservation culture is defining market forces. Energy is an integrated component of all decision making.
- People are energy literate. They measure and manage their energy use. People are proud of conservation and understand the cost of energy just like their do a carton of milk or a litre of gasoline.
- Sustainability and systems thinking is embedded in all education. Energy awareness and leadership are built through effective integration into school curriculum, professional training and certification. Colleges, Universities and trade associations make sure that accurate information on sustainability is widely available. Children are educated about renewable energy as an ongoing part of the curriculum.
- Home based, renewable energy and conservation are status symbols.
- A culture of knowledge exchange exists among the professions and trades.

Green Energy is Preferred

Advanced Renewable Tariffs Promote Green Energy

- All renewable and distributed energy is purchased through advanced renewable tariffs with differentiated pricing based on costs plus a reasonable return on investment, an obligation to connect and priority grid access. Connection costs are included in distribution rates.

401 Richmond Street West, Suite 401
Toronto, Ontario M5V 3A8
(t) 416.977.4441 * (f) 416.977.2157
www.greenenergyact.ca

- All Ontarians can generate renewable energy through their homes and locally owned community power organizations such as co-operatives, municipalities, First Nations, farmer collaborative and institutions. Renewable energy infrastructure is in place to facilitate the maximum potential for local renewable energy.
- Techniques and technologies for electricity storage are effectively deployed to mitigate intermittency of wind and solar and to smooth peak demands.

A Smart Green Grid Enables Easy, Economic and Reliable Access for all Consumers and Generators.

- The Ontario Power Grid has been redesigned by world's leading professionals to support sophisticated responsive and adaptive management.
- The grid is truly bi-directional allowing for economic and reliable distributed energy at all levels.
- The gird is resilient, flexible, adaptive, clean, open to all generators, easy to access, based on distributed clean and renewable energy and benefits from significant levels of demand management. Grid costs are fully rate based.

Green Communities are Served by Green Utilities

Communities Have Become Enablers and Guardians of Sustainability

- Communities are fully engaged and enabled to make the best use of local renewable resources. First Nations can readily access energy opportunities.
- Governance structures are renewed to reflect ultimate goals of sustainable communities and reflect regional goals and local community needs. Decisions are community based.
- Ontario has a world leading public transit system powered by renewable energy, including safe bike lanes. Local community planning drives the development of walk-able communities and low impact transportation. Sustainable transportation is based on non polluting electricity.
- Urban and design and infrastructure minimizes energy use, maximizes green energy sources and encourages active, healthy living. Our urban areas are intensified and neighbourhoods are self-contained: live, work play. Our land base is utilized to its optimum capacity including the production of energy from biomass.
- Waste diversion is maximized and what cannot be diverted is used to produce clean energy.

Utilities Build and Manage Local Green Energy Infrastructure

- Utilities love that they are obligated to connect renewable energy projects and willingly maximize conservation and distributed generation due to their evolved business model.
- Local utilities are freed of regulatory restrictions and provided the commercial incentive to embrace the development of the smart grid, distributed generation and conservation,
- Local utilities are encouraged to develop their distribution systems as smart, dynamic, two way networks to support significant conservation, demand management and distributed energy.

401 Richmond Street West, Suite 401
Toronto, Ontario M5V 3A8
(t) 416.977.4441 * (f) 416.977.2157
www.greenenergyact.ca

Green Energy Act Alliance

Our Homes and Buildings are Green

All Ontarians Live and Work In Affordable, Healthy and Comfortable Buildings.

- All buildings are beautifully designed and connected and their skins are vegetated, harvesting H2O and energy positive. Codes enable and require net zero buildings. Tax credits are provided for homes that go above and beyond code
- Climate change mitigation is built into all changes to the built environment: green walls, green roofs, permeable paving.
- Government has implemented codes and standards to ensure our equipment, homes and businesses are the most efficient when built and when retrofitted. An automatic review process is built in to continually adopt best practices. The building code includes:
  - Measuring, monitoring, managing and benchmarking building energy uses
  - Mandated requirement for solar thermal systems for new buildings and substantial retrofits.
  - Enabling features for distributed energy
  - Making use of unproductive roof surfaces to generate electricity (solar power) or reduce energy use (green roofs).
  - Energy labeling requirements that must be up to date at time of sale.

Comprehensive Conservation Programs Reflect Continuous Improvement Approach

- Programs address all forms of energy as well as water.
- Programs are holistic and delivered through industry groups and trade associations in partnership with local distribution utilities.
- Programs include technical training, technology development and reflect best practices in other jurisdictions.

The Government is Green

- Consultation with First Nations is enshrined in legislation
- Effective public policy has made Ontario a world leader in developing and attracting green technologies and industries. Policy and programs adapt and evolve based on best practices and innovation, guided by core sustainability principles.
- Ontario uses power of provincial procurement policy to drive green change

All Ministries, Agencies and Government Programs Drive Investment in the Green Economy

- Legislation, regulation and taxing regimes are modernized to remove barriers and promote sustainability. Legislated tools for regulators and other decision makers can override existing mandates in the name of sustainability.
- Ontario legislation (e.g., *Planning Act, Electricity Act, Condo Act,* and *Cooperatives Act*) and regulatory frameworks (codes, taxation and systems) have been overhauled to remove barriers to renewable energy systems and to promote sustainable systems.

401 Richmond Street West, Suite 401
Toronto, Ontario M5V 3A8
(t) 416.977.4441 * (f) 416.977.2157
www.greenenergyact.ca

Green Energy Act Alliance

Economics are Green

- All Ontarians understand that clean and renewable energy are the best economic choices once externalities are included in the alternatives. The provincial government has made the financing of green energy dependent on a publicly accepted statement showing a detailed account of life cycle costs of all alternatives. New nuclear plants are allowed but only if private proponents accept market pricing, and liability for operating risk and eventual decommissioning.
- Prices are fair and transparent; externalities and non energy related benefits are recognized for all forms of generation, scale of generation and ownership modes. The full lifecycle cost of energy, including an environmental damage is reflected in the price
- Everyone has access to the energy they need, but we are constantly reducing the quantity of energy necessary to meet these needs. Low income Ontarians have access to energy services at a price they can afford. Energy poverty is eliminated through complementary conservation and public policy.
- Local energy supply options are valued and effectively integrated into the grid, e.g. local bio digesters in rural communities reduce line losses and infrastructure costs.
- Financing tools are available to enable distributed energy, local ownership, conservation and a smart grid. Banks understand and embrace long term financing of energy projects.
- Funding is available for R&D to develop new generation and energy infrastructures that support distributed renewable, clean energy and conservation.

Exhibit “D”

401 Richmond Street West, Suite 401
Toronto, Ontario M5V 3A8
(t) 416.977.4441 • (f) 416.977.2157
www.greenenergyact.ca

Green Energy Act Alliance

RATIONALE
For the Green Energy Act

Rationale for Elements of the Proposal for an Act Granting Priority to Renewable Energy Sources to Manage Global Climate Change, Protect the Environment and Streamline Project Approvals

"Will you leave the earth in better shape than when you found her?"

Honourable George Smitherman, Speech to the Canadian Club, October 31, 2008

January 9, 2009

Ontario Sustainable Energy Association • Community Power Fund • First Nations Energy Alliance • Ontario Federation of Agriculture
Environmental Defence • Ivey Foundation • Pembina Institute • David Suzuki Foundation

Contents

1. Preamble

Ontario is a world leader in the effort to arrest global climate change and the protection of green space. In the face of predicted extraordinary population growth and development pressure over the next thirty years, strong action is needed to make Ontario a global leader in the development of green energy sources –i.e. renewable energy, clean distributed energy and conservation– creating thousands of jobs, economic prosperity, energy security, and climate protection. Public bodies, aboriginal communities, labour and most especially rate-payers share an interest in the generation of electricity and the conservation and management of energy demand that ensures the adequacy, safety, sustainability and reliability of electricity supply in Ontario for both present and future generations. The development of green energy sources should be possible by all Ontarians to enable community groups, first nations, municipalities, farmers as well as the commercial sector to benefit from this quickly emerging industry. The Proposed Green Energy Act for Ontario would serve as the basis for a green industrial strategy for Ontario increasing economic stimulus at the local level across the province, creating jobs that are distributed and diverse as well as provide Ontarians with a renewed sense of ownership in the power sector as they are enabled to participate directly as generators and conservers.

2. Purpose

The purpose of the Act should be to facilitate the development of a sustainable energy economy that protects the environment while streamlining and improving the environmental and planning approvals process, mitigating climate change, engaging communities and building a world-class green industrial sector. The Act must enable all Ontarians to participate and benefit from green energy as conservers and generators, at the lowest cost to consumers. The Act should facilitate green energy deployment by all developers, including the community power sector. The same process, procedures and rules apply to all developers although the Act should provide the community power sector financing support to enable projects to get started.

RATIONALE

The best example of a Green Energy Act is Germany's *Erneuerbare-Energien-Gesetz (EEG),* or, as it is known in English, the *Renewable Energy Sources Act 2000.* It enshrined the concept of feed-in tariffs that are credited with creating a world-beating industry in 15 years. Latest figures show that 250,000 people are now employed in German in the green energy sector.[1] Ontario's Green Energy Act Alliance proposes to build on this model and address additional matters such as the role of energy utilities, access to energy for low-income Ontarians, the modernization of the energy sector with smart grid technologies and the expanded participation of First Nations in the energy sector.

Why Ontario Needs a Green Energy Act

[1] BMU (German Federal Environment Ministry) (2007) *General Information – Renewable Energies,* available at:http://www.bmu.de/english/ renewable_energy/general_information/doc/ 4306.php

A recent report by the World Watch Institute, funded by the United Nations Environmental Program, Green *Jobs: Towards Decent Work in a Sustainable, Low-Carbon World* provides an excellent overview of the changes required to ensure that a jurisdiction can benefit from a green economy. The report defines green jobs as work in agricultural, manufacturing, research and development, and administrative and service activities that contribute substantially to preserving or restoring the environment. Specifically, but not exclusively, this includes jobs that help to:

- Protect ecosystems and biodiversity.
- Reduce energy, materials, and water consumption by being more efficient.
- De-carbonize the economy.
- Minimize or altogether avoid generation of all forms of waste and pollution.
- From a broad conceptual perspective, employment will be affected in at least four ways, as the economy is oriented toward greater sustainability:
- In some cases, additional jobs will be created, for example, by manufacturing devises that control pollution that are added to existing production equipment.
- Some employment will be substituted when shifting from fossil fuels to renewables: for example, manufacturing rail cars instead of trucks or recycling instead of burying and incinerating waste.
- Certain jobs may be eliminated without being directly replaced such as when packaging materials are discouraged or banned and their production is discontinued.
- Many existing jobs (especially those of plumbers, electricians, metal workers, and construction workers) will simply be transformed and redefined as day-to-day skills, work methods, and profiles are greened.

A successful strategy to green the economy involves environmental and social full-cost pricing of energy and materials inputs, in order to discourage unsustainable patterns of production and consumption. In general, such a strategy is diametrically opposite to one where companies compete on price, not quality; externalize social and environmental costs; and seek out the cheapest inputs of materials and labour. A green economy is an economy that values nature and people and creates decent, well-paying jobs.

World Watch Institute

A successful strategy to green the economy involves environmental and social full-cost pricing of energy and materials inputs, in order to discourage unsustainable patterns of production and consumption. In general, such a strategy is diametrically opposite to one where companies compete on price, not quality; externalize social and environmental costs; and seek out the cheapest inputs of materials and labour. A green economy is an economy that values nature and people and creates decent, well-paying jobs.

World Watch Institute

Green jobs span a wide array of skills, educational backgrounds, and occupational profiles. This is especially true with regard to so-called indirect jobs such as those in supplier industries. Even for new industries such as wind and solar power, supply chains consist largely of very traditional industries. For instance, large amounts of steel are incorporated into a wind turbine tower. Technological and systemic choices offer varying degrees of environmental benefit and different types of green employment. The implications of controlling pollution are different from preventing pollution, as does climate mitigation compared with adaptation; efficient buildings vis-à-vis retrofits or public transit versus fuel efficient automobiles. These choices suggest that there are “shades of green” in employment: some are more far reaching and transformational than others.

Drivers for Green Jobs

Companies and regions that become leaders in green innovation, design, and technology development are more likely to retain and create new green jobs. The key drivers of green employment are:

- **Energy Alternatives**: Adopt innovative policies to overcome barriers to developing renewable energy, including feed-in laws that secure access to the electrical grid at guaranteed prices.
- **Subsidies:** Phasing out subsidies for environmentally harmful industries, and shifting a portion or all of those funds to renewable energy, efficiency technologies, clean production methods, and public transit.
- **Training:** Economies such as Germany’s are already facing a shortage of trained workers for the green economy. Ontario’s colleges have begun expanding their programs in related areas, but a broader provincial strategy is needed.
- **Carbon Markets**. Fixing the current shortcomings inherent in carbon trading and Kyoto Protocol related innovations such as the Clean Development Mechanism so that they can become reliable and adequate sources of funding for green projects and employment.
- **Tax Reform**. Scaling up eco-taxes, such as those adopted by a number of European countries, and replicating them as widely as possible. Eco-tax revenues can be used to lighten the tax burden on labour while discouraging polluting and carbon-intensive economic activities.
- **Targets and Mandates**. Ensuring that regulatory tools are used to the fullest extent in the drive to develop greener technologies, products, and services—and thus green employment. This includes land-use policies, building codes, energy efficiency standards (for appliances, vehicles, etc.), and targets for producing renewable energy.
- **Product Take Back**. Adopt “extended producer responsibility” laws (requiring companies to take back products at the end of their useful life) for all types of products.
- **Eco-labelling**. Adopt eco-labels for all consumer products to ensure that consumers have access to information needed to make responsible purchases (and hence encourage manufacturers to design and market more eco-friendly products).
- **Research and Development Budgets**. Reduce support for nuclear power and fossil fuels and provide more funds for renewable energy and efficiency technologies.

- **Bulk Purchasing**: Enable community power to access/purchase critical generation, transmission and storage technology without requiring 'economies of scale' at the local level.

For countries or regions that have suffered job losses due to de-industrialization (such as the so-called U.S. "rust belt" or the former East Germany), the development of wind and solar technology offered a welcome alternative.

In the building sector and elsewhere in the economy, defining the energy-efficiency sector is a vexing problem since most of the relevant forms of employment are embedded in a broad range of existing industries such as vehicle manufacturing, construction, lighting, heating and cooling equipment, electronics, appliances, and so on. Efficiency measures in the building sector include greening buildings and retrofitting as well as improving the efficiency of individual building components including water heaters, cooking equipment, domestic appliances, office equipment, electronic appliances, heating, ventilation and air conditioning systems, and lighting. Macroeconomic studies, most of which have undertaken in the United States and European Union, show that these energy-efficiency measures lead to an overall net increase in jobs. This positive result of both protecting the environment and generating employment is known as the "double dividend."

BUILDING AN ENERGY SECTOR FOR THE 21ST CENTURY

Ontario's energy system developed and evolved over the last century. During the first half of that century, increasing economies of scale resulted in declining electricity prices. Electrification revolutionized our homes and farms, and cheap energy fuelled an expanding manufacturing base.

And even though this recipe for success ended when the nuclear energy industry's promise of power too "cheap to meter" failed to materialize, deep in the Ontario psyche, no doubt stimulated by the rushing roar of water falling at Niagara, there remains an expectation of cheap and reliable power.

Albert Einstein is often quoted: ***Insanity: doing the same thing over and over again and expecting different results***. Ontario is in danger of doing just that with Ontario's current approach to planning for electricity production. When higher than expected costs for Ontario's existing nuclear plants threatened low electricity prices, Ontario Hydro lengthened the amortization period for the assets. Since then, the nuclear fleet has been refurbished long before the expected end of its life, again understating the true cost. Removing most of Ontario Hydro's debt from the companies that emerged when the Ontario Hydro was restructured in the late 1990s further camouflaged the true costs of nuclear power. And while other jurisdictions estimate that new plants will cost upwards of $7,000-10,000 per kW, the Ontario Power Authority, in its Integrated Power System Plan, estimates the cost to be only $2,900.

Planners of traditional power systems consider renewable energy unreliable, intermittent and expensive – each an anathema to their credo of "reliable, continuous and cheap". Similarly, they discount conservation as ethereal, unsustainable, and at best (or worst) enabling consumers to purchase more energy using equipment.

Unless we change the fundamentals of our energy system, unless we create a new paradigm, the existing barriers to renewable energy and conservation will make these traditional views a self-fulfilling prophecy. The benefits of sustainable energy outweigh any deficiencies, and these deficiencies can be overcome by taking a systematic approach: using storage, complementary systems, smart technologies and above all conserving as much energy as possible.

Some of the barriers to sustainable energy are the unintended consequences of policies, legislation, regulations and practices that have little to do with the increasingly wider array of options for renewable energy and conservation. Recently, the City of Toronto passed an overarching bylaw that superseded elements in 17 different bylaws that prevented homeowners and businesses from installing solar panels on their rooftops.

Other barriers result from the rules, regulations and practices in the energy sector itself. While no one questions that the new transmission lines from Bruce to Milton will be included in Hydro One's rate base and recovered from all electricity customers, there is no symmetrical expectation for sustainable energy projects: anaerobic digesters on farms, solar panels on homes or wind farms. Hydro One even assigns monthly charges to a windmill as if it were a customer, although it actually generates electricity.

Other barriers also result from asymmetry. Huge investments in central generating plants or pipelines are recovered through regulation or power purchase agreements over the life of the asset, and financed accordingly. And while the Renewable Standard Offer Program went some way to creating symmetry for wind and solar projects, geo exchange systems, solar thermal, district energy, combined heat and power are constrained by the short-term payback expectations of decision makers for these systems as well as their investors having no similar regulatory or contractual protection.

Any sustainable energy developer in Ontario can describe a litany of roadblocks, barriers and catch 22s encountered on a road to a project. Perhaps the most problematic is the "status quo": the "traditional mindset" that this is the "way we have always done it". But, as we transform the electricity sector from a system based on large, remote central generating plants connected with miles and miles of transmission lines to a more decentralized system with net zero homes, buildings, subdivisions, communities linked by a web of pipes and wires, new ways will have to be developed to empower people, developers, municipalities and distribution utilities to do things differently. If computers still required key punch cards, how many of us would have home or desktop computers? How many of us would walk to the library to look up Einstein's quote on insanity rather than "google" insanity and find Einstein's quote in the third reference?

3. Definitions

Green energy refers to energy sources with low to no environmental impact and includes conservation, renewable sources of energy and clean distributed energy. Renewable energy refers to energy generated from natural resources that are replenished in perpetuity—sunlight, wind, rain, plant materials, ocean and earth energy. Renewable energy technologies include solar panels, wind turbines, small hydroelectric plants, bio-energy (biomass and biofuels), and geoexchange systems. Clean distributed energy sources include, district heating and cooling, combined heat and power, and local generation from waste heat, geothermal and atmospheric energy, (including recycled exhaust heat from gas pipeline compressor stations and energy produced on site at low pressure sources of natural gas currently being flared).

Community Power means energy projects that are locally sited with majority ownership by one or more members of a local community. This includes ownership by First Nations, farmers, public sector institutions, community organizations, co-operatives, remote diesel dependent communities, renters and homeowners, condominiums. Municipalities and local utilities enable Community Power by engaging local community members as owners in projects.

Advanced Renewable Tariffs (ARTs) are a market mechanism used to procure renewable sources of energy. ARTs specify the amount that renewable generators are paid for the electricity they generate and how long they will be paid. In most jurisdictions tariff prices are set by the regulatory authority through an open and transparent process involving all relevant stakeholders. Generally, tariff prices are established at a rate that enables developers to cover the cost of their projects and to earn a reasonable return on their investment. Tariff prices are set based on information from and relevant to the jurisdiction at hand. Tariff prices are adjusted on a regular basis to take into account changing costs. Each project is paid the relevant tariff rate on the basis of their output (per kWh of electricity produced), calculated in much the same way as electricity from conventional power plants have been regulated in North American for many decades. ARTs are usually characterised by the following key features:

- the right of a generator to connect to the grid
- tariff differentiation by technology, resource intensity and project size
- projects are inflation index protected
- no cap on project size and voltage

Although ARTs are generally used for renewable energy, such tariffs can also apply to clean distributed generation and possibly conservation.

Capacity factor refers to the ratio of the actual output of a power plant over a period of time and its output if it had operated at full nameplate capacity the entire time. To calculate the capacity factor, the total energy a plant has produced during a period of time is divided by the energy the plant would have produced at full capacity. Electrical energy is usually measured in kilowatt hours, or megawatt-hours. Kilowatts or megawatts alone are not units of energy. They are units of power. Energy is power multiplied by time. Capacity factors vary greatly depending on the type of fuel that is used and the design of the plant, for example, the capacity factor of a wind farm is between 20 and 40% depending on the location.[2]

DEFINING GREEN ENERGY

Green energy includes conservation, renewables and clean distributed energy supported by micro grids and storage.

CONSERVATION

Any measure that reduces a customer's overall demand for energy and/or a customer's demand for purchased energy. Specifically, conservation includes:

- energy efficiency
- behavioural and operational changes, including application of benchmarking, interval meters or "smart" control systems
- load management -- interruptible and dispatchable loads, dual fuel applications, thermal storage, and demand response
- Fuel switching which reduces the total system energy for a given end-use.

RENEWABLES

Wind power: Modern wind turbines range from around 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use. The amount of power produced by a turbine is calculated by the cube of the wind speed, so as the speed of the wind increases, the amount of power increases dramatically. Areas where the wind is stronger and more constant, such as offshore and in high altitudes are preferred locations for wind farms. Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. Typical capacity factors are 20-40 per cent, with values at the upper end of the range in particularly favourable sites.

Water power: Different structures of water power suit different locations depending on terrain, the amount of water available, environmental impacts, construction and operating costs, local demand, and economic viability. Although electricity cannot be stored, the water storage (or reservoir) of water power facilities has the capacity to generate electricity that can be activated almost immediately to respond to sudden changes in demand. Water power facilities can be characterized by the degree to which they store water. The five main types are:

[2] Taken from http://en.wikipedia.org/wiki/Capacity_factor#Capacity_factor_and_renewable_energy

Run-of-river: A run-of-river facility uses only the natural flow of the river, to generate electricity. Therefore, all the flow of the river either passes through the plant, or is partially released around the plant if the flow exceeds the capacity of the plant to use all of it.

Run-of-river with modified peaking: Many run-of river plants allow for limited storage of water over the course of the day or days. This allows the plant to produce more electricity during periods of high demand i.e., during the day/work week, and save water during periods of low demand i.e., at night/weekends. This type of plant can service the electricity system, but with limitations imposed by the amount of storage and flexibility available (generally from a head pond).

Reservoir storage and cascade systems: These are water power projects that use reservoirs to store water when the flow is high, such as during the spring. The stored water is then used to generate electricity when the flow is low such as during the winter or summer. Reservoirs may be managed specifically for water power production at the site and may also serve a series (or cascade) of facilities downstream. Note that this type of management regime is also used for purposes other than generating electricity (e.g., flood control). Big Eddy, High Falls and Nairn on the Spanish River are a good examples of cascading systems.

Pumped storage: Pumped storage facilities pump water from a lower reservoir to a higher reservoir during off-peak periods. This water is then released from the upper reservoir through the plant to generate electricity during peak periods, e.g., Sir Adam Beck's pumped storage facility at Niagara Falls. The key to the success of this type of plant is to spend less money pumping the water up to the higher reservoir than is made when the water is released to generate electricity. In ideal conditions, pumped storage is the perfect partner for wind energy: wind energy can help pump the water to the higher reservoir when the wind is available and allow the water power to feed the grid during the peak or high load times.

Kinetic water power: Kinetic water power systems are an emerging technology in Ontario. Turbines are placed in the river and use only the existing flow to generate electricity – there is no head involved. Kinetic systems produce less energy per unit volume of water and are generally used for small-scale projects such as a remote cottage or resort.

Solar energy can be applied in many ways, including to:

- Generate electricity by heating trapped air that rotates turbines in a solar updraft tower.
- Generate electricity using photovoltaic solar cells.
- Generate electricity using concentrated solar power.
- Generate hydrogen using photo electrochemical cells.
- Heat and cool air by using solar chimneys.
- Heat buildings, directly, by designing the building to harness passive solar building design.
- Heat foodstuffs, through solar ovens.
- Heat water or air for domestic hot water and space heating needs using solar-thermal panels.
- Solar air conditioning

Liquid biofuel: Agriculturally produced biomass fuels, such as biodiesel, ethanol and bagasse (often a by-product of sugar cane cultivation) can be burned in internal combustion engines or boilers. Typically biofuel is burned to release its stored chemical energy. Research into more efficient methods of converting biofuels and other fuels into electricity using fuel cells is an area of very active work. Liquid biofuel is usually either a bioalcohol such as ethanol fuel or a bio-oil such as biodiesel and straight vegetable oil. Biodiesel can be used in modern diesel vehicles with little or no modification to the engine and can be made from waste and virgin vegetable and animal oil and fats. Virgin vegetable oils can be used in modified diesel engines. In fact, the diesel engine was originally designed to run on vegetable oil rather than fossil fuel. A major benefit of biodiesel is lower emissions. The use of biodiesel reduces emission of carbon monoxide and other hydrocarbons by 20 to 40 per cent.

Solid biomass: Solid biomass is mostly commonly usually used directly as a combustible fuel, producing 10-20 MJ/kg of heat. Its forms and sources include wood fuel, the biogenic portion of municipal solid waste, or the unused portion of field crops. Field crops may or may not be grown intentionally as an energy crop, and the remaining plant by-product used as a fuel. Most types of biomass contain energy. Even cow manure still contains two-thirds of the original energy consumed by the cow. Energy harvesting via a bioreactor is a cost effective solution to the waste disposal issues faced by the dairy farmer, and can produce enough biogas to run a farm. Wood and its by-products can now be converted through process such as gasification into biofuels such as wood gas, biogas, methanol or ethanol fuel; although further development may be required to make these methods affordable and practical. Sugar cane residue, wheat chaff, corn cobs and other plant matter can be, and are, used quite successfully.

Biogas: Biogas can easily be produced from current waste streams, such as paper production, sugar production, sewage, animal waste and so forth. These various waste streams have to be slurried together and allowed to naturally ferment, producing methane gas. Converting current sewage plants into biogas plants can do this. When a biogas plant has extracted all the methane it can, the remains are sometimes more suitable as fertilizer than the original biomass. Alternatively, biogas can be produced via advanced waste processing systems such as mechanical biological treatment. These systems recover the recyclable elements of household waste and process the biodegradable fraction in anaerobic digesters. Renewable natural gas is a biogas that has been upgraded to a quality similar to natural gas. By upgrading the quality to that of natural gas, it becomes possible to distribute the gas to the mass market via a gas grid.

Geothermal energy: Geothermal energy is obtained by tapping the heat of the earth itself. The International Energy Agency classifies geothermal power as renewable. GeoExchange is the industry's term used to describe an alternative to traditional oil- gas- or coal-fired heating, ventilation and air conditioning (HVAC) systems. GeoExchange systems have also been referred to as earth energy systems, or geothermal heat pump systems. This heat 'exchange' between the ground and the building is accomplished by using standard pump and compressor technology.

Clean Distributed Energy

- District heating and cooling

- Combined heat and power: Combined heat and power systems use the excess heat generated during the normal production of electric power. The heat can be used for a variety of applications, including process heating at an industrial site, to heat air and water, or to generate additional electricity (cogeneration) with a steam generator.
- Local generation that uses presently wasted energy from industrial plants would
- Micro grids within local distribution companies, including private wires and pipes in local geographic areas.
- Geothermal and atmospheric energy.
- Recycled exhaust heat from gas pipeline compressor stations.
- Energy produced on site with low pressure sources of natural gas.

Storage

Pumped water: In many places, pumped storage hydroelectricity is used to even out the daily generating load by pumping water to a high storage reservoir during off-peak hours and weekends, using the excess base-load capacity from coal or nuclear sources. During peak hours, this water can be used for hydroelectric generation, often as a high value rapid response reserve to cover transient peaks in demand. Pumped storage recovers about 75 per cent of the energy consumed, and is currently the most cost effective way of storing mass power. Pumped water systems can come on line very quickly, typically within 15 seconds, which makes these systems very efficient at soaking up variability in electrical demand from consumers. Additionally, a new concept in pumped storage is using wind energy or solar power to pump water. Wind turbines or solar cells that directly drive water pumps for an 'energy storing wind or solar dam' can make this a more efficient process, but are again limited in total capacity. Such systems can cover for windless periods of a few hours.

Batteries: One possible technology for large-scale storage is large-scale flow batteries. Sodium-sulphur batteries have been used for grid storage in Japan and in the United States. Vanadium redox batteries and other types of flow batteries are used for storing energy including the averaging of generation from wind turbines. Battery storage has relatively high efficiency, as high as 90 per cent or better. When plug-in hybrid and/or electric cars are mass produced, these mobile energy sinks could be used to store energy. Vehicle-to-grid technology can be employed, turning each vehicle with its 20 to 50 kWh battery pack into a distributed load-balancing device or source of emergency power. This represents two to five days per vehicle of average household requirements of 10 kWh per day, assuming annual consumption of 3,650 kWh. This quantity of energy is equivalent to between 40 and 300 miles (480 km) of range in such vehicles consuming 0.5 to 0.16 kWh per mile.

Compressed air: Off-peak or renewably generated electricity can be used to compress air, which is usually stored in a geological feature. When electricity demand is high, the compressed air is heated with a small amount of natural gas and then put through expanders to generate electricity.

Thermal energy storage: Off-peak electricity can be used to make ice from water, which can be stored until the next day when it is used to cool either the air in a large building, thereby shifting that demand off-peak, or the intake air of a gas turbine generator, thereby increasing the on-peak generation capacity.

Seasonal thermal storage[3]: Seasonal (or "annualized") thermal storage can be divided into three broad categories:

- Low-temperature systems use the soil adjoining the building to store low temperature seasonal heat (reaching temperatures similar to average annual air temperature), drawing upon the stored heat for space heating. Such systems can also be seen as an extension to the building design, e.g. passive solar building design.

[3] The Drake Landing Solar Community development in Okotoks, Alberta uses solar heated water pumped into a Borehole Thermal Energy Storage (BTES) system.

- Warm temperature inter-seasonal heat stores use soil to store heat, but employ active solar collection in summer to heat thermal banks in advance of the heating season.
- High temperature seasonal heat stores are essentially an extension of the building's HVAC and water heating systems. Water is normally the storage medium, stored in tanks at temperatures that can approach boiling point. Phase change materials (which are expensive but which require much smaller tanks) and high-tech soil heating systems (remote from the building) are occasionally used instead. For systems installed in individual buildings, additional space is required to accommodate the size of the storage tanks.

Hydrogen: Hydrogen is also being developed as a medium to store electrical power. Hydrogen is not a primary energy source, but a method of storing portable energy because it must first be manufactured by other energy sources in order to be used. However, as a storage medium, it may be a significant factor in using renewable energy. At penetrations below 20 per cent of the grid demand, this does not severely change the economics, but beyond about 20 per cent of the total demand, external storage will become important.

Each choice we make has a "cost." true cost is a combination of the economic, social and environmental costs set against the offsetting benefits associated with each choice that we make.

Interface Corporation website

Each choice we make has a "cost." true cost is a combination of the economic, social and environmental costs set against the offsetting benefits associated with each choice that we make.

Interface Corporation website

4. Targets

Ontario's economy should become the most energy efficient in North America. To achieve this, the Government of Ontario should build on the success of its world-leading Standard Offer Program for renewable electricity to help businesses and residents make the switch to green energy. Transmitters and the IESO shall immediately and as a priority connect plants generating electricity from green energy sources to their systems and guarantee priority purchase and transmission of all electricity from green energy sources at a reasonable cost to ratepayers consistent with the proposed methodology for valuing green energy in section 6.

The Green Energy Act will form an important basis of Ontario's Climate Change Strategy. In order to meet its goals while creating a world-leading industry, the Green Energy Act should set the following targets:

- 10,000 MW of new installed renewable energy by 2015, over and above 2003 levels
- 25,0000 MW of new installed renewable energy by 2025, over and above 2003 levels
- 1500 MW of new installed CHP by 2015, 3000 MW by 2025, above levels already in place as of the introduction of this Act
- 6,300 MW of conservation by 2015 (beyond 2005 levels) with an additional 2.5% annual (compounding) reduction in energy resource needs from CDM between 2011 – 2027
- 30% reduction in end-use natural gas consumption by 2017

5. Procurement Order

Before committing to new conventional generation supply sources, The Government of Ontario and its designated authorities should pursue the following (in priority):

- All economic conservation
- All economic renewable generation
- All economic waste heat recovery
- All economic dispersed, high efficiency generation

Rationale

In 2003, the three key energy agencies in California – the California Energy Commission (CEC), the California Power Authority (CPA), and the California Public Utility Commission (CPUC) – came together in a spirit of unprecedented cooperation to adopt an "Energy Action Plan" (EAP)[4] that listed joint goals for California's energy future and set forth a commitment to achieve these goals through specific actions. California's Energy Action Plan illustrates the use of a procurement order, termed there as a loading order. The following is an excerpt from the California document.

---

[4] EAP I can be viewed at the CPUC's website at http://www.cpuc.ca.gov/PUBLISHED/REPORT/28715.htm> or at the CEC's website at <http://www.energy.ca.gov/energy_action_plan/2003-05-08_ACTION_PLAN.PDF>.

Our overarching goal is for California's energy to be adequate, affordable, technologically advanced, and environmentally sound:

- Energy should be adequate and reliable, provided when needed and where needed.
- Energy must be affordable to households, business and industry, and avoid environmental damage.
- We must use advanced technologies and we need to improve economic and environmental conditions to lead the way to a better energy future.

These goals affirm the original objectives of EAP I. We will achieve these goals by implementing specific and measurable actions throughout California's energy sector. In a significant expansion of the electricity and natural gas focus of EAP I, the scope of this new Road Map includes transportation fuels, reflecting the importance of these energy resources in California's energy picture and the potential impacts of their use on the environment. It also emphasizes that research, development and demonstration activities are critical to implementing energy goals.

We continue to support strongly the **"loading order"** – endorsed by Governor Schwarzenegger – that was at the heart of the first EAP and which describes our preferences for future resource additions.

- It has energy efficiency and demand response as the State's preferred means of meeting growing energy needs.
- After cost-effective efficiency and demand response, we turn to renewable sources of power.
- To the extent efficiency, demand response and renewable resources are unable to satisfy increasing energy and capacity needs, we support clean fossil-fired generation.
- Simultaneously, the bulk electricity transmission grid and distribution facility infrastructure will be improved to support growing demand centers and the interconnection of new generation. We also see the need to provide open, transparent, and compelling information and education to all stakeholders and consumers in the State.
- The agencies are committed to more effective information dissemination through increased cooperation among all branches of government, businesses, and energy organizations.
- In particular, we pledge to remove remaining barriers to transparency in the procurement processes in the State and to increase outreach to consumers by providing improved education and services regarding energy efficiency, demand response, rates, climate change, and the opportunities to reduce the environmental impacts of energy usage.

6. Valuing Green Energy

The Green Energy Act should base policy and energy choices on the delivered costs of power. In valuing green energy, Ontario must determine what is "economic" by counting all system benefits including: peak and average loss reductions, transmission and distribution savings and externalities. The Ontario Green Energy Act should recognize the added value of distributed energy and conservation by:

Including the value of avoided transmission and distribution capital investment when generation is local; and the value of reduced line losses associated with remote central generation that force the system to generate 18 to 20 per cent more power at peak than system demand

Valuing the difference in redundancy requirements between a system of multiple smaller generators closer to load (three to five per cent to achieve comparable reliability) from a system of a few very large generating stations (18 to 21 per cent redundancy of generation and transmission)

Rationale

It is important to put all energy resources on a level playing to compare their costs and benefits. The most widely used method for doing this is known as the California Standard Practice, which was developed for conservation but is easily transferable to all forms of green energy. Its key elements include the following:

- **Total resource cost test:** Compares the **benefit** of savings (avoided costs to the electricity system) against the **cost** of savings on a **net present** value basis adjusting for estimated **life span** of the conservation measure
- Conservation measures are only considered **economic** if they cost less than new conventional supply and it is desirable to **maximize** the amount saved.

The optimum level of conservation is not the "cheapest":

- All kW and kWh are not equal: "load shape" of conserved electricity is important to understand its value to customers and the system.
- Sustainable savings have greater value than those lasting the life of the measure: e.g. screw in light bulbs vs. lighting redesign.
- Most cost effective savings are designed at the outset – lost opportunities in new construction and renovation should be avoided.

Impact of Conservation on Electricity Rates vs. Electricity Bills

Typically, the percentage reduction in electricity bills far exceeds the percentage increase in electricity rates caused by conservation. Ratio of percentage changes

- 2:l for the surplus system
- 5:l for the base system, and
- 8:l for the deficit system

Given that Ontario has to rebuild 80 per cent of its generating capacity over the next two years, conservation is very desirable economically.

7. Green Energy Procurement

The Ontario Green Energy Act must prioritize green energy development over other forms of new generation and obligate the responsible power purchase authority to grant priority purchase to green energy.

The Green Energy Act should establish Advanced Renewable Tariffs as the principle procurement mechanism for green energy. To ensure projects are economically viable in communities across the province, the tariffs must be based on the following key components:

Tariffs are differentiated on the basis of:

- technology
- resource intensity
- project scale
- location

Prices are set on the basis of cost and a reasonable return on investment with a minimum profitability index of 0.1 for lowest yield and 0.3 for highest yield green energy projects;

- No cap on project size
- No cap on program size
- No cap on voltage – distribution and transmission connected projects
- The tariffs payments will apply to all 'behind the meter' green energy projects
- 100% inflation protection at 2 levels, at both the project level (within the power purchase contracts), and at the program level for future projects.

Currently the Ontario Power Authority is using a combination of Request for Proposals and the Renewable Standard Offer Program (a variation of feed-in tariffs, but limited to distribution connected projects under 10 MW) to renewable energy. The Minister of Energy also asked the OPA to create a Clean Standard Offer Program in August 2005, which has not yet been implemented. Advanced renewable tariffs will enable rapid development of all types of green energy. Not only do they deliver more energy at a lower cost, advanced renewable tariffs will:

- Encourage broad participation.
- Eliminate barriers to renewable generation.
- Provide a stable market.
- Stimulate new investment.
- Provide a rigorous pricing model for setting fair and equitable tariffs.
- Be simple, comprehensible, and transparent.
- Provide simplified interconnection.
- Provide sufficient price per kilowatt-hour to drive development.
- Provide contracts of a length sufficient to reward investment

8. Tariffs

The Ontario Green Energy Act should establish the specific prices for the system of Advanced Renewable Tariffs through an open and transparent process that uses the Profitability Index Model for Setting Renewable Energy Tariffs that was developed for France by Bernard Chabot.[5] Tariff prices should be set for each technology proposed, based on the expected cost to a developer to develop and build a project (where price will be determined according to a variety of variables including technology, resource intensity, project scale, and project location). By providing project developers with increased certainty and the prospect of earning a reasonable rate of return, ARTs allow broad participation in and increased local benefits from renewable energy, create a stable investment climate attracting investment and creating jobs - the basis for a strong green industrial strategy.

Ontario's Advanced Renewable Tariffs should be reviewed by the Government of Ontario every two years to assure developers, investors, manufacturers and service companies program consistency, stability and continuity while avoiding overpayment. The goal will be to maintain the Profitability Index throughout the program as per those levels identified in the section above.

Ontario's Advanced Renewable Tariffs should be monitored to determine if the growth in green energy is sufficiently robust to meet the government's targets. Further, the review would determine if development is being overly concentrated in certain areas to the exclusion of others, and if opportunity for ownership is equitably available to all citizens. Monitoring should include:

Number of operating installations of each technology

Amount of capacity installed relative to applications for grid connection

Growth rate of new capacity

Amount of renewable generation in kWh delivered

Proportion of wind development owned by communities

Proportion of solar development by homeowners, and

Proportion of development in urban and rural areas

The Lieutenant-Governor-in-Council should be empowered to make Regulations respecting the setting of Advanced Renewable Tariffs for, but not limited to, the following technologies:

[5] Profitability Index is the net present value of a project divided by the initial investment. It is a pricing system developed by the oil and gas industries and adopted by the Government of France in setting their tariffs. The oil and gas industries typically achieve a profitability index of 0.7 or 0.8. A core principle of this proposal for a Green Energy Act is that green energy projects make a reasonable profit at a reasonable cost to electricity consumers. The Green Energy Act Alliance is proposing a minimum profitability index of 0.1 for lowest yield and 0.3 for highest yield green energy projects in Ontario, the minimum necessary to spur significant green industrial development.

Solar PV, Solar Thermal

Bio-energy including on farm Biogas

On Shore Wind, Off Shore Wind

Geothermal

Hydro

Storage

Clean distributed energy such as district heating and cooling, combined heat and power, and local generation from waste heat, atmospheric energy, recycled exhaust heat.

In setting Advanced Renewable Tariffs, it is imperative that the authority charged with that task does so in an open and transparent process in consultation with all stakeholders. The process and calculation model for defining the tariffs is a critical factor in their success, which cannot be decided without a full and open discussion.

Rationale

With regularly reviewed advanced renewable tariffs, developers, investors, manufacturers and service companies will be assured that there will be no sudden changes in the program in response to changing political winds. Shorter review periods early in the program's life will allow parties to become familiar with the process, comfortable with the pace of development and aware of the remaining barriers.

With advanced renewable tariffs as the procurement mechanism for clean energy, a reasonable price for clean, local energy will unleash a flood of creativity that will spawn new centres of excellence and create multiple benefits, including:

- Development of new technologies to recycle more of the waste energy.
- Creation of new local industries to manufacture the various forms of equipment needed to capture waste energy and to export such equipment from the province.
- Significant reduction of the costs of manufacturing at most provincial manufacturers, inducing added production, jobs, and higher provincial tax revenues
- Slashing of CO_2 emissions, while improving the provincial economy, making Ontario a focal point of world climate change policy.

By having grid operators take on the necessary costs for upgrading the grid and recovering them in rates, those costs will be regulated to ensure the necessary transparency. By allocating those across the entire rate base, the price of green power will be on a level playing field with the existing and proposed centralized generation.

With advanced renewable tariffs there can be incentives to manage generation. Such an agreement can take fluctuating electricity supplies into consideration in a way that enables the costs for grid upgrades, reserves and stand-by energy to be minimized.

9. Obligation to Connect

Grid connection is essential for the successful application of an Advanced Renewable Tariff program. The Green Energy Act must provide:

- **Priority Grid Access:** An obligation by transmitters, distributers and the IESO to grant priority grid access to green energy projects.
- **Obligation to Connect:** An obligation by utilities to connect green energy projects to the grid (within a reasonable limit to be determined by relative costs and goals related to the successful implementation of the *Green Energy Act*). Transmitters, distributers and the IESO must give immediate priority to connecting installations for the generation of electricity from renewable energies to their grid and to transmitting all the electricity available from these installations.
- **Recovery and Allocation of Costs:** Transmitters and distributers should be entitled to recover all related costs. Related costs are to be spread equally across the rate base. The grid upgrading costs must be declared to ensure the necessary transparency. This obligation aims, in the interests of consumer protection, to prevent costs being shifted unfairly to the electricity purchaser.

10. Financing Green Energy

The Ontario Green Energy Act should mandate the establishment of a Green Energy Debt Finance Program.

- **The Green Energy Debt Finance Program** would be mandated to raise the financial capital required to meet the financial market short falls in the development of eligible and viable projects (individual, community and commercial) to meet the Green Energy Act targets. The intent is that over time the market and community will meet all financial requirements for these projects. Vehicles such as Green Bonds could be implemented under this program to raise a portion of the required capital.

RATIONALE

11. Community Energy

The Ontario Green Energy Act should recognize that:

- Locally owned green energy and conservation activity creates greater economic benefits than centralized electricity generation and
- Community actors are not eligible for the same tax benefits of private developers and therefore the Act should provide preferential tax treatment for private co-investment in community energy projects.

The Ontario Green Energy Act would enable or establish:

- **Community Energy Planning:** By selecting and configuring energy related activities, a community may structure a long-term strategy to reduce its fossil energy dependency and encourage local self-reliance as well as determine the optimum location and density for land intensive renewable energy developments. Just as ratepayers have funded the Integrated Power System Plan (IPSP), energy consumers should fund local energy planning. In many cases, resources are also required for small communities, First Nations and farmers in order to equip them with the technical resources to assist in planning and development.
- **Community Energy Ownership:** Community energy refers to energy projects that are locally planned and sited with majority ownership by First Nations, farmers, public sector institutions (e.g. schools), community organizations, cooperatives, remote diesel dependent communities, renters and homeowners, condominiums, municipalities and/or local utilities.
- **A Community Power Corporation** necessary to ensure the equal opportunity for participation of the community power **sector** in recognition of the additional social and economic benefits of these projects to Ontario communities and the people of Ontario as a whole. The mandate of the Corporation would be to build the capacity of local communities to undertake community energy planning as well as develop eligible and viable projects, provide funding for planning and project development, and to facilitate the develop of financing mechanisms. This corporation will require an initial investment of $50 million.
- **Expanded role for local distribution companies:** Participation of local distribution companies in planning, investment, management and operation of community energy systems and micro grids including the obligation to connect green energy projects, enable them to develop, own and expand local generation with a transparent cost recovery process.
- **Land pool leasing arrangements:** Where developers, community based or private sector, lease land to erect energy resources, the benefits of such leases should be spread across the affected community or landholders rather than only the landholders who host generation facilities.

12. Engaging First Nations and Métis Communities

The Green Energy Act must use Advanced Renewable Tariffs as the main procurement process for green energy. Using Advanced Renewable Tariffs as the main procurement process for sustainable energy will also go a long way to addressing the critical issues affecting both consultation with First Nations and their participation in projects.

With respect to consultation, any mechanism that facilitates discussion outside the pressures and competition of an RFP process would be a great improvement. With respect to participation, Advanced Renewable Tariffs will avoid the barriers inherent in an RFP process that create unique hurdles that prevent successful First Nations and Métis development of green energy projects.

Rationale

First Nations and Métis are included in the definition of "communities". Generally speaking, their views, issues and opportunities are aligned with the other communities. However, as energy proponents, First Nations encounter unique and additional barriers. Further, participation in green energy projects provides a concrete opportunity for economic development for them.

Currently OPA RFPs use a rated criteria method to distinguish and short list potential candidates. The RES III RFP grants point to proponents who meet the following thresholds criteria: environmental assessment, zoning, equipment, resource availability, proponent team and financial assessment. Up to a total of 20 points are allocated to each of environmental assessment and zoning and proponents need at least 40 points to move on to the next round.

- Few First Nations' projects have reached that level, so from the outset they are disadvantaged.
- For non-First Nations developers, RFPs create a false level of consultation during the pre-bid phase and "no alternative but" situation after the contract is awarded.

By requiring the government and First Nations and Métis to work together to prescribe a consultation process, which would be first of its kind, more certainty would be created for First Nations, developers and the province. A comprehensive (one-window) approach to consultation will lead to meaningful engagement of First Nations and Métis in the renewable energy sector and create

- consistency and strong relations
- the necessary context for successful consultations

The current IPSP consultations and regulatory hearings are mostly about large generating plants and trunk transmission lines. Such topics, while important to First Nations, are secondary to regional/community energy planning including regional economic development. These topics are equally important to farmers in rural areas of Ontario and areas of Ontario that need more economic development opportunities.

Local planning and consultation would contribute to the IPSP environmental sustainability criteria thereby creating one continuous consultation mechanism (which will build capacity among First Nations much more effectively than individual sporadic, patchy consultations).

Such a solid consultation process will lead to effective engagement of First Nations and Métis communities in clean power projects and there are options with benefits that go far beyond adhering to legal obligations.

A system that builds strong relations will lead to collateral benefits for non-First Nations proponents by reducing their early development costs and by promoting streamlined development timelines and address existing issues and barriers:

- The most significant stumbling block to successful consultations on the IPSP has been the general failure to ensure that First Nations understand the IPSP within the context of proposed energy projects and within the context of their communities and traditional territories. Significant resources are spent on talking to First Nations about “high level” matters without success.
- Both IPSP and RFP consultations pose unique issues and barriers: IPSP consultations are broad and vague, but on-going; RFP consultation are site specific and focused, but time sensitive and costs get added to the developer’s bottom line.
- The IPSP consultation process has left First Nations with feelings of frustration, confusion and distrust. The main problem has been approach and missed opportunities.
- The IPSP is a “high level” document with little discussions about specific projects. In fact, senior executives in the OPA have indicated that they do not view regional planning as within their mandate, but if not the OPA, than whose? First Nations, on the other hand, (just like other citizens) want to know about what changes/improvements/opportunities are taking place in their backyards. In this regard the community planning elements that would engage communities, including First Nations, in local energy planning would address this gap.
- Public funds are being spent by the OPA to meet legal obligations yet no one is better off in the end. First Nations are intervening in the OEB review process, which is onerous and not proactive.
- RFP consultation, while project based and specific, does not facilitate the time or degree of analysis required to properly safeguard traditional territories. To be fair to proponents, RFPs are competitive processes;why should they get bogged down at the start of the race?

13. Grid Upgrades and Evolution

To accommodate the increasing amount of green, distributed generation the Ontario grid will need to be upgraded and evolved in line with other jurisdictions. The *Ontario Green Energy Act* should:

- Enable the grid (transmission, distribution, system/market operation and energy storage) to become “smart”, “green” and “healthy”
- Remove the barriers to green energy that currently exist in legislation, regulations, codes, standards and market rules
- Encourage and enable other transmitters to develop grid assets and provide them the same preferential status to transmission rights of way enjoyed by Hydro One
- Strengthen the transmission system to enable the achievement of the supply mix goals set out on in the directives and the Green Energy Act
- Promote system efficiency and congestion reduction and facilitate the integration of new supply, all in a manner consistent with the need to cost effectively maintain system reliability
- Provide incentives for operators of Advanced Renewable Tariff funded projects to agree on generation management with the grid operators in their mutual interest. This is especially relevant for grid upgrading and stand-by energy. Such an agreement can take the at times fluctuating electricity supply into consideration in a way that enables the costs for grid upgrades, reserves and stand-by energy to be minimized. To facilitate better integration of renewable energies into the electricity system, there will be an obligation for developers to measure and report the capacity for installations with a capacity of 500 kilowatts or more
- Encourage storage, which is “green energy”. Maximizing the use of storage will increase the availability, reliability and efficiency of green energy.

RATIONALE

Making the grid smart will be the equivalent to bringing the power of the Internet to the transmission, distribution and use of electricity. The development of modern micro-electronics and especially the entry of the microprocessor created ways to significantly improve control of the power grid. The evolutionary integration of intelligent, distributed, and highly adaptive control systems made available with microelectronics includes the possibility to reduce power consumption at the client side during peak hours (demand response), facilitating grid connection of distributed generation power (with photovoltaic arrays, small wind turbines, micro hydro, or even combined heat power generators in buildings), grid energy storage for distributed generation load balancing, and improved reliability against many different component failure scenarios (in contrast to today's catastrophic widespread power grid cascading failures). In addition, real time visibility of embedded generation would assist the IESO and grid operators in maintaining reliability when the real time visibility of the net load at connected transformer stations may not be sufficient.

A smart grid is a transformed electricity transmission and distribution network that uses robust two-way communications, advanced sensors, and distributed computers to improve the efficiency, reliability and safety of power delivery and use. The term smart grid may best be defined as using communications and modern computing to upgrade the current electric power grid so that it can operate more efficiently and reliably and support additional services to consumers. Such an upgrade is equivalent to bringing the power of the Internet to the transmission, distribution and use of electricity - it will save consumers money and reduce CO2 emissions.

Today's alternating current power grid was created in 1896, based on Nikola Tesla's design published in 1888. Many implementation decisions that are still in use today were made for the first time using the limited emerging technology available 120-years ago. Specific obsolete power grid assumptions and features (like centralized uni-directional electric power transmission, electricity distribution, and demand-driven control) are the result of experimental 19th century possibilities.

Smart Grid Technology Score Card[6]

Impact: Does it make the power system more reliable, efficient, predictive or interactive?

- Improves power system wide-area reliability
- Improves power system efficiency and optimization
- Improves prediction and simulation of power system operation
- Improves matching of power supply with demand, e.g. markets
- Improves consumer participation in the power system

Openness: Is the technology freely and widely available?

- Intended to encourage communication between devices and systems
- Interface specifications are published
- Interface specifications are implemented by multiple (many) vendors
- Interface specifications are reviewed and updated by users
- Can be deployed without using or revealing proprietary intellectual property

Standardization: Are the interfaces defined according to recognized standards?

- Uses standards recognized by industry
- Uses standards recognized by a national body
- Uses standards recognized by an international body
- Is certified by an independent organization
- Is certified according to standardized test procedures

---

[6] www.smartgridnews.com: *Smart Grid Scorecard 2008_01_16*

Security: Does it protect critical information and manage who is authorized to access it?

- Authenticates and authorizes users according to their roles
- Protects consumer, business and operational information
- Detects attacks and intrusions
- Permits centralized management of security credentials
- Permits logging and auditing of important operations

Manageability: Does it permit the monitoring and control of performance, configuration, health, accounting, and security?

- Permits or performs remote determination of health
- Permits or performs remote enable/disable of devices or functions
- Permits or performs time synchronization sufficient for application
- Reports or gathers operational and communications statistics
- Reports or gathers alerts and warnings

Upgradeability: Does it permit additions, changes or improvement of key features later?

- Permits remote download of software or firmware
- Permits remote download of configuration, features, or settings
- Permits remotely changing security algorithms and credentials
- Permits remotely changing communications technology
- Integrates well with older versions

Scalability: Does it permit future expansion?

- Contains no fixed limits on growth
- Permits and encourages configuration version control
- Can be deployed at millions of sites
- Co-exists with or improves legacy systems
- Can be deployed at a variety of locations in the power system

Extensibility: Does it make it easier to integrate new devices and applications?

- Automatically detects changes in topology or configuration settings
- Designed in small modules with standardized interfaces
- Publishes or describes what data and services are available
- Shares a standardized information model across the system
- Separates definition of information from how it is transported

Cost-Effective: Does it add measurable business value to the organization using it?

- Has well defined and published performance standards

- Has been tested to performance standards
- Reduces installation or maintenance costs
- Reduces operational costs
- Enables new businesses, products or services

Self-Healing: Does it recover automatically from failures?

- Operates during power outages
- Permits or performs automatic choice of communications path
- Integrates communications and power system failure management
- Encourages distributed decision-making close to the point of impact
- Encourages coordination over a wide area and recovery from failures

Interactivity: Does it help the grid and its users react to each other's needs?

- Encourages consumers to be aware of the energy they use
- Creates new choices for consumers
- Encourages participation in energy markets
- Minimizes visibility of technology
- Permits exceptions and special cases

Healthy Grid

Issues related to electricity pollution in homes, businesses and on farms issues that originates from misdirected currents, can be mitigated. When instead of flowing back to its neutral due to overload, currents flow into the ground to produce high frequency currents, which are harmful to people, animals and equipment that are "electrically sensitive" causing health problems in some cases.

Electrical pollution researchers and those trying to stop its spread claim that the only way to fix this growing problem is to encourage the passage of legislation and the enforcement of regulations to be strictly followed by utility companies. The Electrical Power Research Institute (EPRI) and the Institute of Electrical and Electronics Engineers (IEEE) have identified remedies for electrical ground currents (www.electricalpollution.com/legislation.html). These remedies correct routing problems and keep electricity at clean levels of 60 Hz when entering environments like homes or office buildings. These remedies would be templates for regulation of utility companies to clean up its dirty electricity.

By enabling communities and consumers to take advantage of distributed energy, Ontario will develop a significant aggregate contribution to the security of supply for Ontario consumers

By enabling the transmission elements of the Minister's Supply Mix directive to the Ontario Power Authority to be fully realized the transmission system will be strengthened and:

- Facilitate the development and use of renewable energy resources such as wind power, hydroelectric power and biomass in parts of the province where the most significant development opportunities exist.

- Promote system efficiency, reduce congestion reduction and facilitate the integration of new supply, all in a manner consistent with the need to cost effectively maintain the system's reliability."

Providing other transmitters the same preferential status to transmission rights of way enjoyed by Hydro One will minimize costs and create innovation and a true basis for cost discovery.

In so far as generation procured through Ontario's advanced renewable tariffs is not part of the wholesale market, the IESO market rules that apply to market participants and embedded generators should be replaced with a set of more appropriate **system rules** that r focus on safety and reliability, uncomplicated by the added requirements of market rules.

By transforming local distribution companies and making them part of the community-based energy systems where they earn not on the transportation of ever higher amounts of energy, but on the contribution to helping local communities develop green energy, they will have an incentive to assist participants to understand and conform to **system rules**. Potential items to be included in such performance standards include:

- Power factor requirements for host distribution systems or connected wholesale customer stations connected to the IESO controlled grid (ICG)
- Reactive power control requirements for net power injection into the ICG,
- Dynamic reactive power compensation requirements,
- Review and coordination of under frequency generator tripping requirements for embedded generators connected behind a transformer station and under frequency load shedding requirements for host distribution systems over frequency tripping and automatic reconnection

This will also ensure that local distribution companies will facilitate connection and system impact assessments, assisting producers and their contractors in ensuring the successful integration of embedded generation and improved system reliability.

14. Conservation

Ontarians say overwhelmingly that they want it to be easier to practice conservation. The Green Energy Act must mandate the commitment to a continuous improvement approach to conservation programs, representing a minimum 2.5% annual (compounded) reduction in electricity resource need. With respect to gas conservation, the Act should require that the Ontario Energy Board regulate in a manner that requires the pursuit of all cost-effective conservation by the gas distribution utilities[7]. The Green Energy Act would mandate the provincial government to regulate these improvements.

The Green Energy Act can support and enable a culture of conservation by:

- Empowering consumers to make informed decisions by providing them with information on rating systems, building labelling, energy performance benchmarks, and energy assessment tools. Ensure energy consumers receive regular feedback on their energy consumption and relative energy performance compared to their customer class
- Ensuring a portion of the net benefits of conservation are available for energy conservation programs covering research, development, education, market transformation, training, codes and standards, rating systems, implementation, monitoring and evaluation
- Providing financing for programs that help communities, individuals and businesses to improve energy efficiency and increase conservation in order to reduce their energy bills
- Tightening energy efficiency in the Ontario Building Code and the Energy Efficiency Act. Require all energy efficiency standards to be reviewed and brought up to the international best practice on a three-year cycle
- Educating Ontario students of all grades on environmental protection, energy efficiency and conservation as key elements of good citizenship
- Ensuring end users pay the real price of energy, which will result in a reduction in consumption so that energy costs represent a decreasing share of disposable income
- Ensuring that smart metering and billing infrastructure is in place for real-time pricing of energy (and water) and user pay principles are in effect through individual metering and sub metering
- Protecting vulnerable energy consumers through direct install conservation programs, bill assistance through universal service plans and emergency assistance. These elements are necessary prerequisites to the ability of this customer class to benefit from sub metering
- Protecting energy intensive industries by providing a double rebate for annual energy savings through conservation in excess of 10 per cent
- Supporting greening programs (e.g. roofs, urban forestry etc.) through financing programs, incentives and building codes

[7] See Appendix 1 for OEB Guidelines for Gas Utilities.

Rationale

By pursuing all of the economic conservation the current narrow and piecemeal approach to conservation will be addressed.

Problems with the current approach include:

- Cream skimming- going for the cheapest conservation, not the most conservation that is cost effective compared to supply.
- Lack of comprehensive framework and market strategy
- Electricity versus gas and water, load displacement technologies, fuel switching
- Market cannibalization, particularly in Toronto: BOMA, Vs Toronto Hydro, vs. City of Toronto
- Separation of functions within OPA
- Truncation of role of the Conservation Bureau and chief energy conservation officer
- Ignoring the full life cycle benefits of conservation
- Picking technology and supplier winners
- Structure of contracts with local Electric distribution utilities

Including Green Roofs and Living Walls as Conservation Measures

Green roof technology is an important conservation measure, reducing energy demand for air conditioning from five to 60 per cent in summer and providing benefits from insulation in winter subsequently reducing gas and/or electricity consumption. Through the process of evapo-transpiration of water, green roofs cool the surrounding air thereby reducing the urban heat island effect and reducing the temperature of intake air for air conditioning systems increasing their efficiency by as much as 12 per cent. Green roofs also improve the efficiency of roof mounted solar photo-voltaic panels by between five to 25 per cent, depending on design factors.

- Green roofs can help manage the quality and quantity of storm water, provide recreational space, extend the life of roofing membranes, be used to grow food (urban agriculture), reduce smog and particulate matter in the air, and provide opportunities for biodiversity. Despite their many benefits, wide-spread implementation of green roofs is challenged by their upfront costs that are higher than conventional roofing - particularly for commercial and industrial building.
- To address this barrier, the Green Energy Act should support a green roof program in Ontario with an incentive of $50 per square meter of installed green roof infrastructure that would apply to all multi-unit residential buildings (over two stories), institutional, and commercial buildings, for both new construction and building retrofit. The incentive would require that the green roof cover a minimum of 50 per cent of the roof, and that the growing medium be at least eight centimetres thick. This incentive would help to offset the higher upfront cost of a green roof infrastructure while ensuring that there is sufficient green roof covering to benefit the public.

Barriers to Conservation

There are a number of key market barriers that impede the timely, economic adoption of measures to use energy more efficiently and economically. These have been well documented in the literature. Although significant progress continues to be made in certain areas, major institutional and marketplace barriers exist that delay the implementation of the full potential of energy efficiency in Ontario.

These market barriers are well described and widely accepted[8]. They are referred to below to provide a context for some of the recommendations in this report. The market barriers can be classified into the following five major categories:

- *Inadequate financing* - The lack of a mature market for financingconservation has resulted in limited availability and high financing cost as lenders are not yet familiar with the risks and benefits of energy efficiency projects.
- *Emphasis on first cost* - Conservation is hindered because many consumers and businesses base purchase decisions on the initial capital cost of a product without considering the life cycle operating cost savings.
- *High transaction cost* - Adoption of energy efficient products and practices involves high transaction costs such as learning about efficiency opportunities, difficulty in integrating into complex expansion/renovation projects and the effort needed to coordinate the many diverse elements of an energy efficiency project.
- *Lack of information/limited energy efficiency infrastructure* - Many consumers and businesses are unaware of the opportunities that exist for increasing energy efficiency. They lack information about the anticipated costs and benefits of energy efficiency improvements. They are sceptical about the reliability of claimed savings and/or fear performance will be degraded if they switch to energy efficient products.
- *Regulatory and governmental policies* - Examples of this include lack of policies that reward utilities for encouraging efficiency, and policies that create an incentive for utilities to increase revenues by increasing the quantity of electricity generated, transmitted, distributed and sold.
- *Geographical diversity* - Ontario is a large province with many regions, where distance or population densities make delivering conservation programs expensive. Yet, these regions are frequently where conservation is most needed. For example, in northern Ontario several factors combined make conservation critically important: the older housing stock is inefficient, fuel prices are higher and incomes are lower. The challenge may be on the delivery side, where economies of scale for delivering programs may act as a barrier to cost-effective implementation.[9]

The original intent of the Conservation Bureau was to help coordinate market transformation and conservation activities and provide technical and training support. The following functions are still required to realize this vision:

[8] Ontario's Energy Efficiency Consortium, 1994; Accelerating Energy Efficiency in Ontario
[9] Union Gas, 1998; Demand Side Management Plan: 1999- 2003.

- Provide comprehensive, non-biased information required for conservation planning, analysis and evaluation such as energy efficient technologies, per unit savings, avoided costs.
- Develop provincial-wide planning and evaluation protocols and manage independent third party audits of utility program evaluations.
- Facilitate commercial activities to provide services, products, and processes directly related to conservation, including the introduction and transfer of advanced technologies and management practices from abroad through joint ventures and foreign investment.
- Organize training and demonstration projects in energy efficiency.
- Coordinate and develop educational activities in energy efficiency, including distribution of publications, public education, training classes and seminars.
- Document and make available on-line case studies of successful energy efficiency projects.
- Provide the basis for comprehensive energy efficiency programs that boost local economic activity.
- Work with manufacturers, energy services suppliers, building owners and operators, engineers, architects with respect to provincial, national and international initiatives. For example, new construction, both commercial and residential, is a sector that requires at least provincial wide approaches, with links to codes and standards.

The design and delivery of effective conservation programs depends on continuous research and improvements based on the research. Research falls into four broad categories: technical, market, load research, and research aimed at improving program implementation.

- **Technical research** encompasses product development and manufacturing improvements, performance testing and performance simulation, modifications of products to ensure commercial viability, development of standards and rating systems, and environmental and energy efficiency auditing. This research may take place in the laboratory, in manufacturing facilities, or in pilot installations.
- **Market research** covers both factual profiling of market characteristics – market shares for various technologies, building stock characteristics, equipment replacement rates, for example – and attitudinal sampling among end-use consumers and channel partners.
- **Implementation research** is aimed at establishing the most effective ways of implementing measures to save energy and monitoring and evaluating these measures.
- **Load research** can be defined as work aimed at establishing the amount of electricity consumed under different situations, for different purposes, using different technologies or processes. Techniques for estimating loads include end-use metering, billing analysis, and building simulations. Increasingly, smart metering and the use of the meter data management system will obviate Ontario's need for this research.

Achieving High Participation Rates

One of the goals of a successful conservation program is to achieve high participation rates among customers. High participation rates are required to maximize energy savings and reduce participant costs if utilities are to meet their objectives. The American Council for an Energy Efficient Economy conducted a detailed review of programs in Canada and the United States and 15 attributes of high participation programs were identified.[10] They included:

- Community-based marketing, which seeks to involve the entire community
- Personal contacts with customers to market and assist with programs
- Technical assistance for customers and trade allies
- Provision of high quality services
- Active involvement of trade allies in program design and marketing
- Efficiency thresholds that push the market
- Clear and catchy marketing materials and messages
- Targeted marketing to multiple decision-makers
- Marketing that emphasizes the many benefits of energy efficiency
- Ensuring ease of customer participation, e.g. direct install programs
- Ensuring ease of manufacturer and distributor participation.
- Target “early adopters”, including customers with high-energy bills
- Provide large financial incentives
- Build regional consortiums to promote particular efficiency improvements

Work with government agencies to use utility programs to lay groundwork for mandated equipment efficiency standards and building code improvements.

Conservation Program Development/Implementation

In designing a portfolio of conservation programs, it is necessary to consider all program attributes and conduct a tradeoff analysis. What is important is not necessarily the individual performance of one measure but the overall performance of the portfolio. Even when a portfolio scores low on one impact, CO_2 reduction for example, it might provide an optimal mix of programs when the total benefits and costs are taken into account.

[10] Nadel, S., Miriam Pye, Jennifer Jordan, 1994; Achieving High Participation Rates: Lessons Taught by Successful DSM Programs, ACEEE.

A portfolio is designed to achieve the best mix of programs and elements relative to the objectives in the theme. It should also achieve acceptable performance relative to the other objectives. By minimizing or maximizing a specific characteristic, the size and impact of other characteristics will vary. For example, by selecting programs that have the largest societal net benefits, the cumulative impact on lost opportunities might be significant but the impact on participation by low-income end-use consumers, including First Nations and farmers, may not be acceptable.

There are two parts of portfolio development are:

1. the scenario or theme used to select the level of effort and focus of programs and
2. the types of portfolio impacts [attributes] that should be considered, such as

- **Target lost opportunities*:*** This portfolio is designed to address opportunities that will be lost if timely action is not taken. A good example is the opportunity to promote energy savings when industries embark upon a cycle of new investment. In the residential sector, it means designing programs to ensure that homeowners are presented with energy efficient choices when they buy a new home or make major renovations.
- **Maximize total societal benefits *(Societal Cost Test – SCT).*** To produce high societal benefits, measures are chosen which yield the most energy savings. This means special attention is focused on the industrial sector and within that sector to the small percentage of large consumption end-use consumers. In the residential sector, it means focusing on retrofit activities and equipment standards.
- **Breaking market barriers.** In this strategy the aim is broad coverage. Programs are designed to overcome market barriers and penetrate hard -to- reach markets. This means focusing on small commercial end-use consumers in the business sector and making programs accessible to lower income end-use consumers in the residential sector.
- **Maximize end-use consumer value.** This strategy stresses programs that provide direct benefits to program participants (as compared to society as a whole). Energy service companies and contractors are used to enhance value to participants. Financial incentives and financing are central.

Conservation Portfolio Attributes

By reviewing the attributes associated with each demand side management program, a preferred option can be selected. The attributes that can be used for the evaluation of program options include:

- **Societal net benefits**: This is the net result of analyzing the costs and benefits of a portfolio using the societal cost test. The net benefits are the sum of the costs and benefits of each of the programs.
- **Rate impact**: The percentage increase in rates that end-use consumers pay is a significant concern. For many conservation expenditures, rates may go up but this change is mitigated for program participants by a decrease in their consumption, meaning lower bills. For non-participants, there is no commensurate decrease in bills to offset the rate increase, hence the desire to achieve full participation through well designed and well executed conservation programs.

- **Electricity saved**: The electricity saved is the direct result of the number of participants in the programs and the number and type of measures they install. In addition, the net electricity saved is the total amount that is determined minus that amount that would have been saved had there been no DSM activities.
- **Lost opportunity impact**: This is the degree to which the programs or portfolios bring about energy efficiency improvements that would have otherwise been passed by when energy investment decisions considered only short or medium term impacts.
- **Participation by low-income people, First Nations and farmers**: These end-use consumers spend a higher portion of their income on their utility bills than other end-use consumers. Therefore, the impact of increases in their bills from DSM is higher than the average for these end-use consumers, if they do not participate in the programs. They may also face certain unique barriers (financial and other) to participation in DSM programs.
- **Administrative effort of implementation**: Consideration is made for the level of administrative effort that is required to deliver DSM programs. This includes expenditures, staffing levels, the need for information, and interaction between DSM activities and other activities of the utility or other delivery agent. In addition, the delivery choices may be constrained by the types of delivery channels available or the ability of the utility to influence those channels.
- **Addressing market barriers**: In this attribute the concern is that the breadth of programs be all-inclusive. In addition, programs should include all elements that could significantly affect the participation by end-use consumers.
- **Market transformation**: The long-term evolution of the demand and supply for energy efficiency measures so that consideration of energy efficiency in new or retrofit investment decisions becomes a widely accepted practice.

NEW JERSEY'S ENERGY EFFICIENCY PLAN

The Northeast Energy Efficiency Partnerships (NEEP) recently introduced its comprehensive plan for the state of New Jersey. It represents a standard that Ontario should aspire to replicate. An excerpt follows[11].

Achieving the ambitious NJ EMP 2020 Energy Efficiency Goals requires a major investment in all sectors of the New Jersey economy – approximately $11 billion over the next 12 years to improve the overall energy performance of NJ homes and businesses by 20% relative to current and projected energy use. This investment offers the potential to provide considerable energy, economic and environmental benefits – savings are more than double the costs. But it will take a concerted, well managed and coordinated program and policy effort that leverages resources, builds momentum and instills confidence and good will at all levels – state, local, public and private. To overcome multiple market, institutional and financial barriers to energy efficiency, the NJ EMP Energy Efficiency Initiative will take:

- Bold, inspiring leadership with the political will to encourage statewide collaboration;

[11] For more information or a copy of the plan go to: **http://www.nj.gov/emp/**

- A long-term view to build and sustain market capacities to achieve the 2020 Energy Master Plan Goals.
- A well designed, integrated program strategy that can serve sixty percent of New Jersey's homes and businesses by 2020 with comprehensive, cost-effective efficiency solutions that address all fuels to reduce energy consumption by thirty percent to meet energy, economic and environmental goals.
- A durable, flexible integrated statewide program administrative structure focused on performance and results;
- A positive and stable regulatory environment; and
- A major financial commitment – approximately $11 billion over the next 12 years.

15. Protecting the Environment

The purpose of the Green Energy Act is to protect the environment by establishing a sustainable energy system for Ontario that improves air quality and reduces greenhouse gas emissions. The Green Energy Act must recognize that the principles of environmental protection apply to every energy project and should not compromise human health, community values or natural heritage systems.

The Green Energy Act should amend the *Environmental Assessment Act* and *Planning Act* to:

- Implement a “one project, one process” approach, in order to dispense with the need for green energy proponents to apply for and obtain *Planning Act* approvals and appear before the OMB for new or existing projects which:
    - Have already been approved (or exempted) under the *Environmental Assessment Act* (EA Act); or
    - Are subject to the prescribed planning, documentary and consultation requirements under the *EA Act* (e.g. individual EA, Class EA, or ESP under O.Reg. 116/01); and,
- Amend the *EA Act* in order to impose enhanced public notice requirements for green energy projects to ensure that interested/affected municipalities, stakeholders, and First Nation/aboriginal communities receive timely and adequate notice of their opportunities to participate in the applicable environmental planning process (e.g. individual EA, Class EA, or ESP under O.Reg.116/01). In additio*n, the* Lieutenant Governor in Council should be empowered to make regulations that:
- Contain clear, prescriptive provincial standards for the siting of green energy projects (e.g. “no go” areas, setback requirements, etc.) and that determine areas in need of protection. Restrictions should be technology specific and based on legitimate and peer-reviewed scientific data
- Provide exceptions for First Nations and Métis projects to the greatest extent possible
- Streamline and coordinate environmental assessments and where possible use Class Environmental Assessments. The purpose of a Class EA is to specify a planning process through which environmental impacts and benefits are considered in proposed projects. A Class EA will provide effective and efficient project assessment and public engagement processes that are appropriate for projects within the class. It will ensure that proponents take into account the potential impacts and benefits of proposed projects as well as the interests of individuals, communities, agencies and organizations, as appropriate
- Streamline and coordinate planning and building permit processes

With respect to streamlining approvals under the Class EA process, the Lieutenant Governor in Council should be empowered to make regulations:

- Adjusting project categories or thresholds under approved Class EAs and the ESP so that a greater number of renewable energy projects are fully exempt under the EA Act (but they must still obtain other federal or provincial approvals where applicable)
- Prescribing shorter timeframes e.g. six months, and clearer deadlines for the completion of the planning/review process under approved Class EAs and the ESP

- Limiting grounds for bump-up/elevation requests to matters of provincial interest (as opposed to matters that are essentially local in nature)
- Creating an independent, expedited process for determining bump-up/elevation requests (e.g. written hearing by a member of the Environmental Review Tribunal, or re-establishment of an EAAC-like entity to advise the Minister on such matters)

Depending on the technology and if it is a First Nations Community Energy Project, green energy projects should not be located in, nor cause adverse impacts upon:

- Critical habitat of species listed as endangered and threatened under the Endangered Species Act, 2007
- Provincially significant wetlands, valleys, woodlands or wildlife habitat
- Provincially significant areas of natural, agricultural and scientific interest
- Significant areas of cultural heritage or archaeological value, including First Nations' or aboriginal communities' sacred sites
- Lands designated as Escarpment Natural Area or Escarpment Protection Area under the Niagara Escarpment Planning and Development Act
- Lands designated as Natural Core Area or Natural Linkage Area under the Oak Ridges Moraine Conservation Act, 2001
- Provincial parks and conservation reserves, except in accordance with section 19 of the Provincial Parks and Conservation Reserves Act, 2006

RATIONALE

Clearly the core of the Green Energy Act is protecting the environment and working toward a sustainable energy system for Ontario. While green energy projects will contribute to a sustainable energy future, the Green Energy Act Alliance recognizes that the principles of environmental protection apply to green energy projects. Ontario must find a way to streamline environmental approvals so that the very goals that environmental assessment is to achieve are not frustrated by a misuse of the process.

The Green Energy Act is not as broad in scope of the existing *Environmental Assessment Act*, nor does the Alliance pretend to represent as broad a base of stakeholders necessary for the new vision called for by the Environmental Commissioner of Ontario.

Class Environmental Assessment for Waterpower Projects

The Ontario Waterpower Association, on behalf of its members and the broader water power industry in Ontario, embarked on the development of a Class Environmental Assessment for water power projects in the spring of 2002. The development of a Class EA is a two step process, both of which involve the engagement and involvement of agencies, organizations and the public.

As the proponent of the Class EA, the OWA prepared a term of reference – in essence defining the boundaries of the Class EA. The Minister of the Environment, the Honourable Laurel Broten, in November 2005, approved the OWA's term of reference. Once approved, the Class EA will position the OWA as having lead responsibility for remaining current with best practices and information of direct relevance to water power projects in Ontario, and for providing that material to project proponents. It will also ensure that the OWA continues to foster and maintain positive and productive relationships with those with an interest in water power.

This Class EA will apply to water power projects to which the electricity projects (2001) under the *Environmental Assessment Act* currently or as amended applies. It will apply to all proponents of water power projects in Ontario, regardless of their affiliation with the OWA. A primary objective of the Class EA is to integrate the multiplicity of environmental approvals and public involvement processes that are relevant to planning a water power project. Project proponents adhering to the Class EA are expected to be able to satisfy the core planning requirements for this array of legislation, regulation and policy. Common to all of these processes are the themes of "environmental responsibility" and "public accountability."

This Class EA has adopted these themes and is designed to facilitate coordination with other directly relevant federal and provincial policies, guidelines and legislation. Application of a "one project, one coordinated process" principle facilitates the early identification of environmental considerations and interests of agencies involved. In practice, adoption of this principle should result in a diligent proponent coordinating and satisfying the information and involvement requirements directly relevant to planning a new water power project.

Relationship to Electricity Projects Regulation

This Class EA is intended to replace the portion of the Electricity Projects Regulation (or as amended) that applies to water power projects. In general, the regulation defines three categories of undertakings:

- Category A projects are not subject to provincial environmental assessment requirements (though may be subject to other regulatory provisions).
- Category B projects (the subset or class) require a self-screening and, depending on the outcome, may require the preparation of an environmental report.
- Category C projects require an individual environmental assessment. A deterministic approach to which projects fall within each category has been taken in the regulation, largely premised on the resultant installed capacity of a new electricity project, with some provisions related to the magnitude of change to an existing project. Though the "thresholds" for categorization differ across technologies, an underlying premise of the present regulatory regime for electricity projects is pre-determined differentiation.

The Class EA builds upon the Electricity Projects Regulation and adds the concept of proactive differentiation based on the general environmental context within which a new water power project takes place. As such, the Class EA focuses specifically on projects that are currently included in category B under the regulation and further differentiates them for water power.

Project Streams within the Class

While the characteristics of individual water power projects differ based on factors such as site-specific environmental conditions, location, design, and proximity to a grid connection, there are key differences in the broader environmental contexts within which new projects will be brought forward.

Within the Class EA, water power projects occurring in similar environments have been proactively streamed into categories premised on the general differences in these environmental contexts. At a higher level than the individual project, differences are apparent in three themes:

- **Retrofitting or redevelopment of existing infrastructure**: These are projects occurring where a site-specific "footprint" has already been established and new or increased renewable energy generation is proposed at existing infrastructure.
- **New projects on existing regulated systems**: These are projects that, while establishing a new structure, are undertaken on a system for which water management regimes (generally for multiple benefits) are already in place.
- **New projects on previously unregulated systems:** These projects have the potential to introduce new infrastructure and new water management regimes on a system previously not subject to water level and flow management.

Consultation and Involvement

A key component of the Class EA is the engagement at the project level of First Nations, agencies and the public, as appropriate. By definition, the projects subject to the Class EA are expected to be those for which issues and impacts can be managed and mitigated. That is, pursuant to the Electricity Projects Regulation, they have been determined not to require an individual environmental assessment.

Experience suggests, however, that, in many instances the public and/or representative interests request that individual projects (electricity and other) be required to prepare an individual EA. Experience also shows that relatively few of these requests have that result. It is apparent, therefore, that there is a disconnection between the expectations of participants in the process (including the proponent) and its outcome.

This Class EA seeks to address this challenge in mapping out key project elements and targets, supported by principled and practical approaches to consultation and involvement.

16. Protecting Vulnerable Consumers

Ontario's Green Energy Act should address the matter of energy affordability for Ontario's vulnerable consumers such as seniors, medically infirm and infants and farmers by directing the Lieutenant Governor in Council to make regulations that may include:

- **Conservation:** Programs specifically targeted to low-income households to reduce their energy expenditures on a sustained basis.
  - Conservation programs should address appliances, building envelopes, heating systems (efficiency & fuel switching to more efficient equipment), and cooling systems.
  - Conversion from Electric Heat to replace electric space heating units with thermal storage, or other fuels such as renewables, natural gas, oil etc. as long as the heating equipment is high efficiency.
- **No cut-off policy:** Moratoriums on cut-off should include the following categories: medical, age, temperature and agricultural.
- **Billing and collections:** Requiring all utilities to offer pay-as-you-go payment systems, utilities should develop arrearage payment plans with a certain amount of debt-forgiveness, if the customer keeps up with the payments. Bills will still provide actual consumption data and time of use billing and indicate whether the customer is using more or less energy than the year to date payments have accounted for.
- **Security deposits:** Require all utilities to offer monthly collection of security deposits. [12]
- **Protection from unscrupulous contractors, retailers and landlords:** Ensure consumer protection from high-pressure sales tactics for both commodity sales and energy services and landlords who do not share energy savings with tenants or who fail to maintain minimum conservation standards in their buildings.
- **Bill assistance:** Allow the Ontario Energy Board to make energy more affordable for low-income households on an ongoing basis. Options to be enabled include:
  - **Fixed percentage discount:** Participants receive a fixed percentage discount off their energy bill. In the U.S., these discounts range from 7% to 40%.
  - **Fixed dollar amount:** Participants receive a fixed dollar reduction on their bill, regardless of how much energy they consume.
  - **Variable discount:** Participants' discounts reduce as consumption increases.
  - **Percentage of Income Payment Plan (PIPPs):** Participants pay a fixed percentage of the total income towards their energy bills. PIPPs reduce the energy burden of participants, but provides significant disincentive to conserve energy.
- **Emergency assistance:** Require an ongoing emergency assistance program to address:

An impending energy service cut-off

[12] Where community and social services clients have their energy bills paid through direct deposit exempt them from security deposit requirements. Where clients pay their own energy bill and are advanced the security deposit from Community and Social Services, it should be treated as a loan and repaid.

- A short term spike in energy prices
- The need to replace or repair home heating equipment

RATIONALE

By addressing the matter of energy affordability for Ontario's vulnerable consumers the following conditions can be achieved:

- Considering energy for the safe preparation and storage of food, home heating, and cooling a basic necessity of life.
- Meeting immediate needs of low-income households, and developing sustainable preventative measures for the long term.
- Developing policy and programs in consultation with low-income consumer and advocacy groups. Policy and programs should be applicable to all low-income households including those that pay utilities in their rent and should not result in deductions from other social assistance programs.
- Making the screening process for identifying eligible program participants clear, simple, and easily accessible, and a one-stop application process should be developed accessible by utilities and charitable organizations alike.
- Using Statistics Canada's pre-tax, post-transfer Low-income cut-off values to define low-income households.
- Applying conservation programs that are comprehensive, addressing appliances, building envelopes, heating systems (efficiency and fuel switching equipment), and cooling systems[3].
- Not requiring any upfront capital outlay for low-income participation in energy efficiency upgrade programs. Programs should be paid either as a direct subsidy to low-income consumers or through energy savings on their utility bills. In the latter case, the upfront cost is covered by the energy efficiency program and then recovered by the utility through savings on the participant's utility bill. This ensures that no financial costs are borne by the participant. Any conservation funding should not be clawed back under other social assistance programs.
- Integrating emergency energy assistance programs with other emergency programs such as the Rent Bank.
- Including education as a key component of all the other elements and be coordinated.
- Outreach and education through landlords, social housing providers and local distribution companies[4], e.g. bill inserts.
- Outreach and education about the program through municipal social services agencies, which administer Ontario Works, and Ontario Disability Support Program.
- Outreach and education through charitable organizations, community and advocacy groups (e.g. Green Communities Association, Share the Warmth, Salvation Army, Toronto Environmental Alliance, Advocacy Centre for Tenants Ontario, Income Security Advocacy Centre).

- Outreach and education targeted at special needs of new Canadians (e.g. multilingual communication materials).
- Coordinated advertisements (television, print and radio) and information on linked websites.

Consumer protection initiatives reduce energy burden and protect low-income consumers from the risks associated with high-energy burdens. These include the following:

"No cut-off" policy: Moratoriums for the no cut-off policy should include the following types of customers[5]:

- Medical-based - prohibits disconnection if customer has a serious medical condition.
- Age-based - prohibits disconnection if there are elderly or infants in the home.
- Temperature-based - prohibits disconnection under extreme hot or cold temperatures. This approach provides immediate relief on extreme days, but only provides a temporary solution for a very short period of time.
- Livestock-based - prohibits disconnection under extreme temperatures for bona fide agricultural operations.

Billing and Collections

- Require all utilities to offer equal billing plans to all customers.
- Require all utilities to offer pay-as-you-go payment systems.
- All utilities should develop arrearage payment plans with a certain amount of debt-forgiveness, if the customer keeps up with the payments.

Security Deposits

- Require all utilities to offer monthly collection of security deposits.
- Where ODSP and OW clients have their energy bills paid through direct deposit, exempt them from security deposit requirements.
- Advanced security deposits from Community and Social Services should be treated as a loan and repaid.

Unscrupulous Contractors, Retailers and Landlords

- Ensure consumer protection from high-pressure sales tactics for both commodity sales and energy services and landlords who do not share energy savings with tenants or who fail to maintain minimum conservation standards in their buildings.

Conservation

Conservation programs specifically targeted to low-income households to reduce their energy expenditures on a sustained basis.

- If electric and natural gas utilities are accountable for energy efficiency and conservation, they need to be encouraged to do so aggressively and cost-effectively using local community groups that supply services to low income households and nonprofits with experience delivering energy efficiency programs (e.g. Social Housing Services Corporation, Green Communities Association members) as delivery channels for their low-income energy efficiency and conservation programs.
- Conservation programs should address appliances, building envelopes, heating systems, and cooling systems.
- Energy efficiency standards: Any appliance recycle programs must remove inefficient appliances from the market and assist in the acquisition of new energy efficient appliances. While Ontario has a robust set of energy efficiency standards for new products, rental accommodation often includes older, less efficient appliances.
- Conversion from electric heat to replace electric space heating units with thermal storage, or other fuels such as renewables, natural gas, oil etc. as long as the heating equipment is high efficiency.

Bill Assistance

17. Governance

Transitioning to a more decentralized, community-based, sustainable energy sector requires broad-based institutional support and alignment among government agencies. Better co-ordination and even integration is needed of those agencies that already have responsibility for energy policy and the inclusion of many others that affect its implementation to ensure consistency and support at different levels. The Green Energy Act must address the governance of Ontario's energy sector to realign the roles and responsibilities of provincially owned agencies and create the appropriate regulatory environment and economic incentives for other participants in the sector – both public and private.

The proposed Green Energy Act recommends the creation of a Green Energy Directorate headed by a chief renewable energy officer. This position would complement the role of Ontario's chief conservation officer. Both posts should be positioned within the Ministry of Energy and Infrastructure and would govern the development of green energy across the province, ensuring consistency and development priority of green energy as defined in this document. The Green Energy Directorate should elicit representation and input from a range of government ministries and agencies needed for the successful implementation of all RE applications, but it should have sufficient clout to steer development across the province.

The chief renewable energy officer would be charged with the following responsibilities:

- Assessing barriers to developing green energy and addressing these on a prioritized basis

- Creating alignment among various agencies and streamlining and simplifying the approval process
- Overseeing the annual review of the feed-in tariff and tariff adjustments
- Commissioning independent studies to assess common concerns about RE development
- Identifying gaps in skills and helping determine what training is needed
- Spearheading the industrial strategy, finding ways to attract investment and develop jobs in Ontario
- Overseeing a complaints commission to ensure fair treatment of green energy actors of all sizes
- Representing Ontario in international green energy forums especially the International Feed-in Co-operation and International Renewable Energy Agency (IRENA)

Our largest and most difficult problem to overcome has been the existing laws and regulations governing commerce. The current infrastructure subsidizes unsustainable industrial processes. To make significant progress, we will need the cooperation of government and other industrial partners to shift taxation away from economic and social benefits, (labor, income and investment) to detriments, (pollution, waste, and the loss of primary resources).

Ray Anderson, Chair, Interface Corporation

Our largest and most difficult problem to overcome has been the existing laws and regulations governing commerce. The current infrastructure subsidizes unsustainable industrial processes. To make significant progress, we will need the cooperation of government and other industrial partners to shift taxation away from economic and social benefits, (labor, income and investment) to detriments, (pollution, waste, and the loss of primary resources).

Ray Anderson, Chair, Interface Corporation

18. Appendix 1: E.B.O. 169 - III Guidelines

Appropriate Costing Methodology for Demand Side Options

- The benefits of DSM should be the avoided supply-side costs including capital, operating and energy costs
- Avoided tolls and demand charges should be included as avoided costs of a DSM program
- The avoided upstream costs of TCPL and natural gas producers should be identified when they are known, but should not be incorporated.
- Long run avoided costs over the useful life of a DSM program should be used when defining DSM benefits.
- Emphasis in the analysis should be on the first five years of a DSM program and portfolio when evaluating costs and benefits as well as their performance vs forecasts.
- A break even analysis of each DSM program should be provided.

Cost Effectiveness Tests

When considering which potential programs should be screened for cost effectiveness and incorporated in a DSM portfolio, consideration should be given to achievable goals; the capture of potentially lost opportunities; synergisms among programs; and the breadth of the portfolio.

Once identified, potential programs would be subjected to a screening process that incorporates the following recommendations:

- The societal cost test should be a first screen (Screen 1) and used a pass/fail hurdle (i.e., it would be unreasonable to pursue further a program that does not have a net benefit to society)
- Social costs and benefits should be considered and treated in an equivalent manner to environmental costs and benefits.
- Only those direct and indirect externality costs and benefits that are significant though should be included in the SCT.
- A qualitative assessment of each DSM program, including all program costs and benefits should be carried out to produce a non-monetary conclusion on the net societal benefit.
- Programs that pass the SCT would next be subjected to rate impact measure testing (Screen 2).
- Programs that fail the RIM test may be further considered if the rate impact they would impose is not too great and if second round costs do not exceed the first round net societal benefits (Screen 3).
- The net societal benefit per dollar of subsidy should be provided for each program that fails the RIM test.
- Programs that fail Screen 3 should be further considered as candidate programs if they provide qualitative benefits such as: improved safety and system reliability; avoidance of lost opportunities; recognition of critical or important societal benefits; the need to board the DSM portfolio or support for government policy. (Part 1, Screen 4).

- Each program that has passed Screens 2, 3, 4, (Part 1) should be assessed to determine the program's suitability as a candidate for further consideration in comparison to the other surviving programs.
- Comprehensive approach to programs not single measure programs; all measures passing SCT included.
- All programs should be assessed from a pragmatic point of view regarding the likelihood of their acceptance and success.
- Candidate programs should be consolidated into potential portfolios for evaluation. Each portfolio should be subjected to sensitivity analyses prior to the selection of the ultimate portfolio (Screen 5).
- The screening process and the assumptions used in carrying it out should be clearly documented and presented and the rates case

When assessing what constitutes a reasonable rate impact for programs that have failed the RIM test, consideration should be given to questions such as:

- Will the immediate impact on customers' bills be excessive?
- Is it likely that customers' bills will, in the longer term, be unaffected or reduced even if rates increase?
- Will the impact on certain groups, such as low-income customers, be onerous?
- To what degree will the various stakeholders share in the benefits of a particular DSM program?
- Will the security or the overall cost of operating the utility system be of benefit beyond the first round impacts of the DSM program?
- Will the long-term net societal benefits of the DSM program override its immediate rate impacts?
- Are the net societal benefits of such as magnitude and importance as to give priority to their attainment?
- Do opportunity costs demand prompt action?
- Will an important DSM program be left undone or poorly done, if a ratepayer subsidy is not provided?
- Will the inclusion of the DSM program contribute to a broader menu of programs and thereby recognize the needs and perspectives of groups such as low-income customers, First Nations and farmers that might otherwise be precluded from participating?
- Will the inclusion of the DSM program take advantage of synergies among programs?
- The participant test should be used as one means of evaluating the appropriateness of a proposed customer contribution.
- A portfolio approach should be employed to allow as many customers as reasonably possible to participate and share in the benefits of DSM.

Regulatory Treatment of DSM Investments

To the degree possible, these should be consistency in the regulatory treatment of supply side and DSM costs. The eligible costs of long term DSM programs (i.e., those with a duration of more than one year, including “hardware”, longer-term incentive rebates and loads, labour, overhead and administrative costs, should be proposed for inclusion in rate base.

- Eligible short-term costs expended over a period of one year or less should be consider expenses and recovered through the cost of service in the year incurred.
- Reasonable broad-based information efforts and associated programs should be proposed a legitimate cost of service without necessarily identifying specific benefits that will be obtained, so long as prudence can be established.
- Information and associated programs that are specific to a DSM program should be considered a cost of that program.
- The utilities should co-operate in and, to the extent possible, coordinate their broad-based information and associated program.
- The difference between actual and forecast DSM operating costs, and if necessary, capital expenditures should be proposed to be accrued in deferral or balancing accounts that, together with carrying costs, are to be disposed of at the utility’s next rates case, or as directed by the board.
- DSM efforts should be included as part of utility operations and not “spun”: off” as a non-regulated affiliated business.

Allocation of DSM Costs

To the extent possible, the direct beneficiaries of a DSM program should bear the direct financial burden of a program.

- Customer incentives for purposes such as increasing penetration rates, may be considered when the utility is prepared to justify them.
- The utility should be wary of requiring customer contributions at levels that would restrict participation by groups such a low income customer, or would induce conversions to less environmentally desirable fuels.
- So long as it does not reach undue proportions, some level of cross-subsidization for DSM programs may be proposed for recovery in rates.
- Rate impact s due to DSM program should be treated consistently with the rate impacts from supply-side program.
- While some level of cross subsidization and rate impact may be acceptable, the utility should make every effort to work toward developing self-sustaining program.
- DSM programs designed for large commercial and industrial customers should be identified separately from those directed toward small gas users.
- The utilities to disaggregate plans to recognize peak, seasonal and annual cost impacts for the allocation of demand and commodity charges.

Incentives and Decoupling Mechanisms

If a utility can establish that shareholder incentives are necessary in order to implement DSM programs effectively, it should apply for such incentives when it presents its DSM plan at a rates case and, at that time, also address the need for penalties to be imposed when performance is below expectation.

- If utility incentives are shown to be required, shared savings, based on the nature of urgency of the program, the market being targeted and the degree of difficulty in program implementation should be viewed as the preferred approach to the provision of incentives.
- If shareholder incentives are proposed, on a program or portfolio basis, the level of the shareholders' portion of the savings should be determined on a case-by-case basis.
- Full decoupling should be viewed as an inappropriate mechanism for use in Ontario at this time.
- If a utility considers that a lack of revenue protection is a significant disincentive, it may propose a revenue adjustment mechanism, provided that the impacts that the mechanism has on the utility's risk exposure and earnings are also considered.

Monitoring and Evaluation

The utilities should recognize the need to design effective monitoring and evaluation mechanisms into their DSM programs, in order to evaluate a program's on-going cost effectiveness and success, as well as any need for changes.

When monitoring and evaluating a DSM portfolio, the utilities should provide assurance that the portfolio is fulfilling its expectations with regard to such matters as:

- the breadth of coverage
- the effective use of information and education programs
- cost effectiveness
- achievement of intended objectives
- overcoming anticipated or emerging market barriers; and
- the capture of potentially lost opportunities

The utilities should file base case forecasts of natural gas demand that would be expected in the absence of formal DSM plans.

Initially, the base case forecast should include the impacts of NGV programs and of DSM programs initiated prior to fiscal 1995, together with the assumptions and price expectations underlying the forecast.

The DSM plan and program forecasts should be based on achievable potential, derived to the extent possible from end-use models.

The utilities should report on the degree to which end-use models can be integrated into their forecasts, at the rates case when they file their first DSM plans. The reports should also include the cost, data and time requirements for the implementation of end-use forecasting.

Forecasts of the costs of programs and plans should be provided on both a total cost and unit cost (per unit of demand and/or savings) basis.

For each program and for the overall portfolio, forecasts of the pessimistic, optimistic and most likely impacts on the base case forecast should be presented, along with a description of the major assumptions employed.

Each utility should submit an overview of its DSM plan that describes:

- the goals of its DSM portfolio and how these will be achieved
- the objectives for resource planning and customer service
- specific DSM savings objectives by class of customer; and
- a discussion of the alternative implementation strategies considered

The utilities should cooperate in their use of pilot programs and in the development of standard monitoring and evaluation techniques.

Rate Design and DSM

When developing DSM plans, the need for just, reasonable, stable, cost-related rates should be recognized.

The potential for rate shock should be anticipated and avoided whenever possible.

While there appears to be little current justification for revising rate structures, the utilities should explicitly consider energy efficiency impacts results from rates and rate structures in any future review of rate design.

The utilities should undertake, and periodically update, assessments of the impacts of interruptible rates, since in addition to constraining system costs, such rates can affect the use of alternate fuels.

More explicit billing information (e.g. displays of consumption patterns, as well as capacity, customer and commodity charges) should be provided to customers.

Jurisdictional Concerns

The utilities should not delay or limit the development of their DSM plans pending a resolution of jurisdictional issues.

DSM plans that extend beyond a given test year should be prepared under the assumption that once their consequences are approved by the board, panels in future proceedings will be sensitive to the need for consistency in the treatment of prudent long-term DSM plans.

When funding is required for effective consultation, the utilities should directly provide such funding in the expectation that prudent expenditures will be recoverable in rates.

Implementation of DSM

The utilities should present DSM plans in their filings no later than for their fiscal 1995 rates cases. Should this be onerous, a utility should request, as soon as possible, an extension of the timetable.

The utilities should bring forward evidence on the development, implementation monitoring and evaluation of DSM programs, portfolios and plans for review by the board in the context of rates cases, rather than in parallel hearings.

The utilities should consult with appropriate parties in an effective manner to obtain meaningful input related to each of the major steps in the DSM planning process.

The utilities should report, when filing a DSM plan, on the planning process, including the consultative process, used to develop that plan.

The utilities should take advantage of DSM delivery mechanisms, such as those available from ESCOs, rather than commenting with, or supplanting them.

Cooperation with ESCOs should extend to expanding their involvement with both the large and small user groups.

Where appropriate, programs should be designed to consider all energy conservation opportunities, rather than just focusing on natural gas conservation measures in isolation.

The utilities should cooperate with organizations such as Ontario Hydro and the municipal electric utilities to implement broad-based conservation programs.

The Board is aware that gas IRP is in its infancy across North America. As a result, the Board anticipates that the initial DSM plans and forecasts may require adjustments as experience is gained during their implementation. The Board feels it is appropriate to learn by doing, rather than wait until a higher level of certainty is achieved. Thus, while the Board will expect the utilities to commit to their DSM plans, and to work diligently toward their achievement, the plans should allow for the flexibility to make mid-course corrections and adjustments when necessary.

Exhibit “E”

Ontario
Executive Council
Conseil des ministres

Order in Council
Décret

On the recommendation of the undersigned, the Lieutenant Governor, by and with the advice and concurrence of the Executive Council, orders that:

Sur la recommandation du soussigné, le lieutenant-gouverneur, sur l'avis et avec le consentement du Conseil des ministres, décrète ce qui suit:

WHEREAS Enbridge Gas Distribution Inc. and related parties ("Enbridge") gave undertakings to the Lieutenant Governor in Council that were approved by Order in Council on December 9, 1998 and that took effect on March 31, 1999 ("the Enbridge Undertakings"), and Union Gas Limited and related parties ("Union") gave undertakings to the Lieutenant Governor in Council that were approved by Order in Council on December 9, 1998 and that took effect on March 31, 1999 ("the Union Undertakings");

AND WHEREAS the Minister of Energy and Infrastructure has the authority under section 27.1 of the *Ontario Energy Board Act, 1998* to issue directives, approved by the Lieutenant Governor in Council, that require the Ontario Energy Board to take steps specified in the directives to promote energy conservation, energy efficiency, load management and the use of cleaner energy sources including alternative and renewable energy sources;

AND WHEREAS The Government of Ontario has, with the passage of the *Green Energy and Green Economy Act, 2009,* embarked upon a historic series of initiatives related to promoting the use of renewable energy sources and enhancing conservation throughout Ontario;

AND WHEREAS certain amendments to the *Ontario Energy Board Act, 1998* provided for by the above-noted statute authorize electricity distribution companies to directly own and operate renewable energy electricity generation facilities with a capacity of ten (10) megawatts or less, facilities that generate heat and electricity from a single source, or facilities that store energy, subject to criteria to be prescribed by regulation;

AND WHEREAS it is desirable that both Enbridge and Union are accorded authority similar to those of electricity distributors to own and operate the kinds of generation and storage facilities referenced above, while clarifying that the latter two activities, namely the ownership and operation of facilities that generate heat and electricity from a single source, or facilities that store energy, are to be interpreted to include stationary fuel-cell facilities each of which does not exceed 10 Megawatts in capacity, as well as to allow Enbridge and Union the authority to own and operate assets required in respect of the provision of services by Enbridge and Union that would assist the Government of Ontario in achieving its goals in energy conservation including where such assets relate to solar-thermal water and ground-source heat pumps;

AND WHEREAS the Minister of Energy has previously issued a directive pursuant to section 27.1 in respect of the Enbridge Undertakings and the Union Undertakings, under Order-in-Council No. 1537/2006, dated August 10, 2006.

NOW THEREFORE the directive attached hereto is approved and is effective as of the date hereof.

Recommended: ______________________
Minister of Energy and Infrastructure

Concurred: ______________________
Chair of Cabinet

Approved and Ordered: SEP 0 8 2009
Date

____
Lieutenant Governor

O.C./Décret 1540/2009

MINISTER'S DIRECTIVE

Re: Gas Utility Undertakings Relating to the Ownership and Operation of Renewable Energy Electricity Generation Facilities, Facilities Which Generate Both Heat and Electricity From a Single Source and Energy Storage Facilities and the Ownership and Operation of Assets Required to Provide Conservation Services.

Enbridge Gas Distribution Inc. and related parties gave undertakings to the Lieutenant Governor in Council that were approved by Order in Council on December 9, 1998 and that took effect on March 31, 1999 ("the Enbridge Undertakings"); and Union Gas Limited and related parties gave undertakings to the Lieutenant Governor in Council that were approved by Order in Council on December 9, 1998 and that took effect on March 31, 1999 ("the Union Undertakings").

The Government of Ontario has, with the passage of the *Green Energy and Green Economy Act, 2009,* embarked upon a historic series of initiatives related to promoting the use of renewable energy sources and enhancing conservation throughout Ontario.

One of those initiatives is to allow electric distribution companies to directly own and operate renewable energy electricity generation facilities of a capacity of not more than 10 megawatts or such other capacity as is prescribed by regulation, facilities which generate both heat and electricity from a single source and facilities for the storage of energy, subject to such further criteria as may be prescribed by regulation.

The Government also wants to encourage initiatives that will reduce the use of natural gas and electricity.

Pursuant to section 27.1 of the *Ontario Energy Board Act, 1998*, and in addition to a previous directive issued thereunder on August 10, 2006 by Order in Council No. 1537/2006, in respect of the Enbridge Undertakings and the Union Undertakings, I hereby direct the Ontario Energy Board to dispense,

- under section 6.1 of the Enbridge Undertakings, with future compliance by Enbridge Gas Distribution Inc. with section 2.1 ("Restriction on Business Activities") of the Enbridge Undertakings, and

- under section 6.1 of the Union Undertakings, with future compliance by Union Gas Limited with section 2.1 ("Restriction on Business Activities") of the Union Undertakings,

in respect of the ownership and operation by Enbridge Gas Distribution, Inc. and Union Gas Limited, of:

(a) renewable energy electricity generation facilities each of which does not exceed 10 megawatts or such other capacity as may be prescribed, from time to time, by regulation made under clause 71(3)(a) of the *Ontario Energy Board Act, 1998* and which meet the criteria prescribed by such regulation;

(b) generation facilities that use technology that produces power and thermal energy from a single source which meet the criteria prescribed, from time to time, by regulation made under clause 71(3)(b) of the *Ontario Energy Board Act, 1998*;

(c) energy storage facilities which meet the criteria prescribed, from time to time, by regulation made under clause 71(3)(c) of the *Ontario Energy Board Act, 1998*; or

(d) assets required in respect of the provision of services by Enbridge Gas Distribution Inc. and Union Gas Limited that would assist the Government of Ontario in achieving its goals in energy conservation and includes assets related to solar-thermal water and ground-source heat pumps;

(e) for greater certainty, the use of the word "facilities" in paragraphs (b) and (c) above shall be interpreted to include stationary fuel-cell facilities each of which does not exceed 10 Megawatts in capacity.

This directive is not in any way intended to direct the manner in which the Ontario Energy Board determines, under the *Ontario Energy Board Act, 1998,* rates for the sale, transmission, distribution and storage of natural gas by Enbridge Gas Distribution Inc. and Union Gas Limited.

George Smitherman
Deputy Premier, Minister of Energy and Infrastructure

Exhibit “F”

Ontario
Executive Council
Conseil exécutif

Order in Council
Décret

On the recommendation of the undersigned, the Lieutenant Governor, by and with the advice and concurrence of the Executive Council, orders that:

Sur la recommandation de la personne soussignée, le lieutenant-gouverneur, sur l'avis et avec le consentement du Conseil exécutif, décrète ce qui suit :

WHEREAS the government adopted a policy of putting conservation first in its 2013 Long-Term Energy Plan, *Achieving Balance.*

AND WHEREAS it is desirable to achieve reductions in electricity consumption and natural gas consumption to assist consumers in managing their energy bills, mitigating upward pressure on energy rates and reducing air pollutants, including greenhouse gas emissions, and to establish an updated electricity conservation policy framework ("Conservation First Framework") and a natural gas conservation policy framework.

AND WHEREAS the Minister of Energy intends to issue a direction to the Ontario Power Authority to require that it undertake activities to support the Conservation First Framework, including the funding of electricity distributor conservation and demand management programs.

AND WHEREAS the Minister of Energy may, with the approval of the Lieutenant Governor in Council, issue directives under section 27.1 of the *Ontario Energy Board Act, 1998* in order to direct the Board to take steps to promote energy conservation, energy efficiency, load management or the use of cleaner energy sources, including alternative and renewable energy sources.

AND WHEREAS the Minister of Energy may, with the approval of the Lieutenant Governor in Council, issue directives under section 27.2 of the *Ontario Energy Board Act, 1998* in order to direct the Board to take steps to establish conservation and demand management targets to be met by electricity distributors and other licensees.

NOW THEREFORE the Directive attached hereto is approved and shall be and is effective as of the date hereof.

Recommended ______________________
Minister of Energy

Concurred ______________________
Chair of Cabinet

Approved and Ordered MAR 2 6 2014
Date

____
Lieutenant Governor

O.C./Décret 467 / 2014

MINISTER'S DIRECTIVE

TO: THE ONTARIO ENERGY BOARD

I, Bob Chiarelli, Minister of Energy, hereby direct the Ontario Energy Board (the "Board") pursuant to my authority under sections 27.1 and 27.2 of the *Ontario Energy Board Act, 1998* (the "Act") to take the following steps to promote electricity conservation and demand management ("CDM") and natural gas demand side management ("DSM"):

1. The Board shall, in accordance with the requirements of this Directive and without holding a hearing, amend the licence of each licensed electricity distributor ("Distributor") to establish the following as the CDM target to be met by the Distributor:

   i. add a condition that specifies that the Distributor shall, between January 1, 2015 and December 31, 2020, make CDM programs available to customers in its licensed service area and shall, as far as is appropriate and reasonable having regard to the composition of the Distributor's customer base, do so in relation to each customer segment in its service area ("CDM Requirement");

   ii. add a condition that specifies that such CDM programs shall be designed to achieve reductions in electricity consumption;

   iii. add a condition that specifies that the Distributor shall meet its CDM Requirement by:

      a) making Province-Wide Distributor CDM Programs, funded by the Ontario Power Authority (the "OPA"), available to customers in its licensed service area;

      b) making Local Distributor CDM Programs, funded by the OPA, available to customers in its licensed service area; or

      c) a combination of (a) and (b); and

   iv. add a condition that specifies the Distributor shall, as far as possible having regard to any confidentiality or privacy constraints, make the details and results of Local Distributor CDM Programs available to other Distributors upon request.

2. Despite paragraph 1, the Board shall not amend the licence of any Distributor that meets the conditions set out below:

   i. with the exception of embedded distributors, the Distributor is not connected to the Independent Electricity System Operator ("IESO") – controlled grid; or

   ii. the Distributor's rates are not regulated by the Board.

3. The Board shall establish CDM Requirement guidelines. In establishing such guidelines, the Board shall have regard to the following objectives of the government in addition to such other factors as the Board considers appropriate:

i. that the Board shall annually review and publish the verified results of each Distributor's Province-Wide Distributor CDM Programs and Local Distributor CDM Programs and report on the progress of Distributors in meeting their CDM Requirement;

ii. that CDM shall be considered to be inclusive of activities aimed at reducing electricity consumption and reducing the draw from the electricity grid, such as geothermal heating and cooling, solar heating and small scale (i.e., <10MW) behind the meter customer generation. However, CDM should be considered to exclude those activities and programs related to a Distributor's investment in new infrastructure or replacement of existing infrastructure, any measures a Distributor uses to maximize the efficiency of its new or existing infrastructure, activities promoted through a different program or initiative undertaken by the Government of Ontario or the OPA, such as the OPA Feed-in Tariff (FIT) Program and micro-FIT Program and activities related to the price of electricity or general economic activity; and

iii. that lost revenues that result from Province-Wide Distributor CDM Programs or Local Distributor CDM Programs should not act as a disincentive to Distributors in meeting their CDM Requirement.

4. The Board shall establish a DSM policy framework ("DSM Framework") for natural gas distributors whose rates are regulated by the Board ("Gas Distributors"). In establishing the DSM Framework, the Board shall have regard to the following objectives of the government in addition to such other factors as the Board considers appropriate:

   i. that the DSM Framework shall span a period of six years, commencing on January 1, 2015, and shall include a mid-term review to align with the mid-term review of the Conservation First Framework;

   ii. that the DSM Framework shall enable the achievement of all cost-effective DSM and more closely align DSM efforts with CDM efforts, as far as is appropriate and reasonable having regard to the respective characteristics of the natural gas and electricity sectors;

   iii. that Gas Distributors shall, where appropriate, coordinate and integrate DSM programs with Province-Wide Distributor CDM Programs and Local Distributor CDM Programs to achieve efficiencies and convenient integrated programs for electricity and natural gas customers;

   iv. that Gas Distributors shall, where appropriate, coordinate and integrate low-income DSM Programs with low-income Province-Wide Distributor CDM Programs or Local Distributor CDM Programs;

   v. that the Board shall annually review and publish the verified or audited results of each Gas Distributor's DSM programs;

   vi. that an achievable potential study for natural gas efficiency in Ontario should be conducted every three-years, with the first study completed by June 1 2016, to inform natural gas efficiency planning and programs. The achievable potential study should, as far as is appropriate and reasonable having regard to the respective characteristics of the natural gas and electricity sectors, be coordinated with the OPA with regard to the OPA's requirement to conduct an electricity efficiency achievable potential study every three-years;

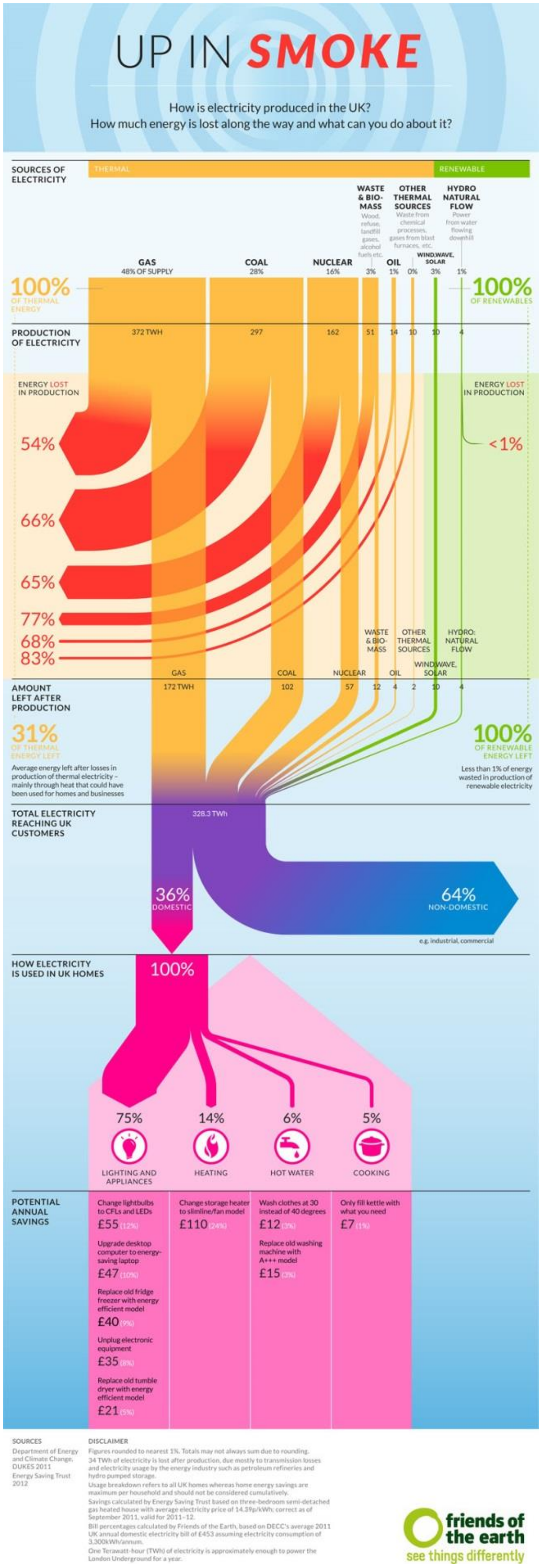
vii. that DSM shall be considered to be inclusive of activities aimed at reducing natural gas consumption, including financial incentive programs and education programs; and

viii. that lost revenues resulting from DSM programs should not act as a disincentive to Gas Distributors in undertaking DSM activities.

5. By January 1, 2015, the Board shall have considered and taken such steps as considered appropriate by the Board towards implementing the government's policy of putting conservation first in Distributor and Gas Distributor infrastructure planning processes at the regional and local levels, where cost-effective and consistent with maintaining appropriate levels of reliability.

6. Nothing in this Directive shall be construed as directing the manner in which the Board determines, under the *Ontario Energy Board Act, 1998*, rates for Gas Distributors or for Distributors, including in relation to applications regarding regional or local electricity demand response initiatives or infrastructure deferral investments.

Exhibit “G”



the Guardian, ***Up in smoke: how efficient is electricity produced in the UK?*****, online: <http://www.theguardian.com/news/datablog/2012/jul/06/energy-green-politics#zoomed-picture>.**

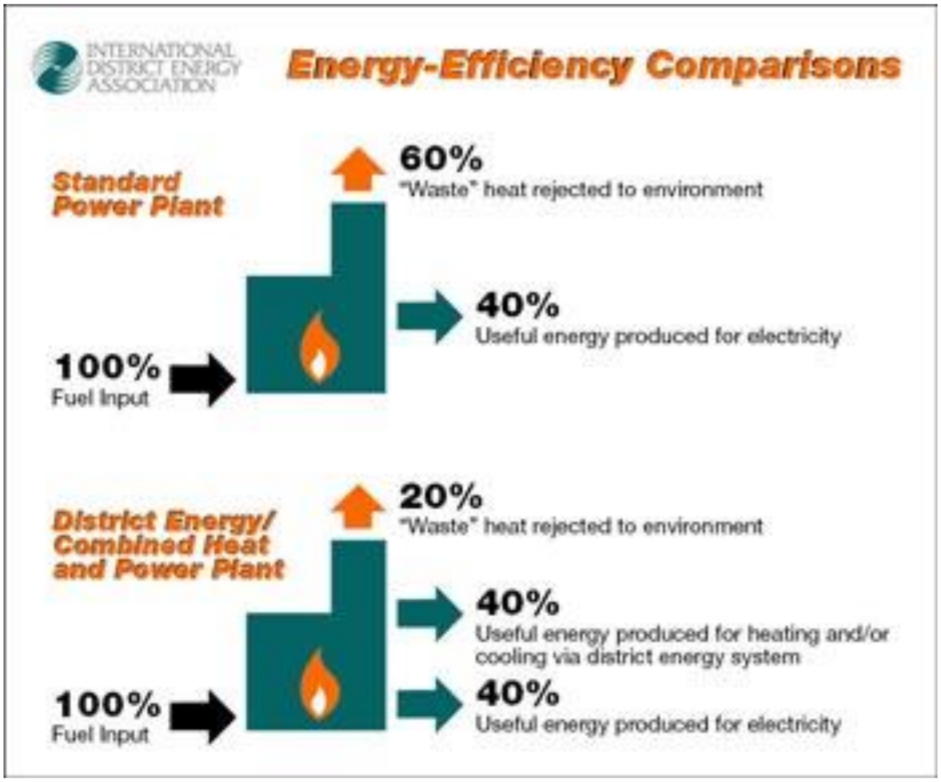
Exhibit “H”

Technology	Fuel	Capacity MW	Electrical efficiency (%)	Overall efficiency (%)
Steam turbine	Any combustible	0.5-500	17-35	60-80
Gas turbine	Gasous & liquid	0.25-50+	25-42	65-87
Combined cycle	Gasous & liquid	3-300+	35-55	73-90
Diesel and Otto engines	Gasous & liquid	0.003-20	25-45	65-92
Micro-turbines	Gasous & liquid	0.05-0.5	15-30	60-85
Fuel cells	Gasous & liquid	0.003-3+	37-50	85-90
Stirling engines	Gasous & liquid	0.003-1.5	30-40	65-85

CHP plants can range from less than 5 kW_e from micro-gas-turbines, fuel cells, gasifiers and Stirling engines (Whispergen, 2005) to 500 MW_e. A wide variety of fuels is possible including biomass (Kirjavainen et al., 2004), with individual installations accepting more than one fuel. A well-designed and operated CHP scheme will provide better energy efficiency than a conventional plant, leading to both energy and cost savings (UNEP, 2004; EDUCOGEN, 2001). Besides the advantage of cost reductions because of higher efficiency, CHP has the environmental benefit of reducing 160–500 gCO_2/kWh, given a fossil-fuel baseline for the heat and electricity generation.

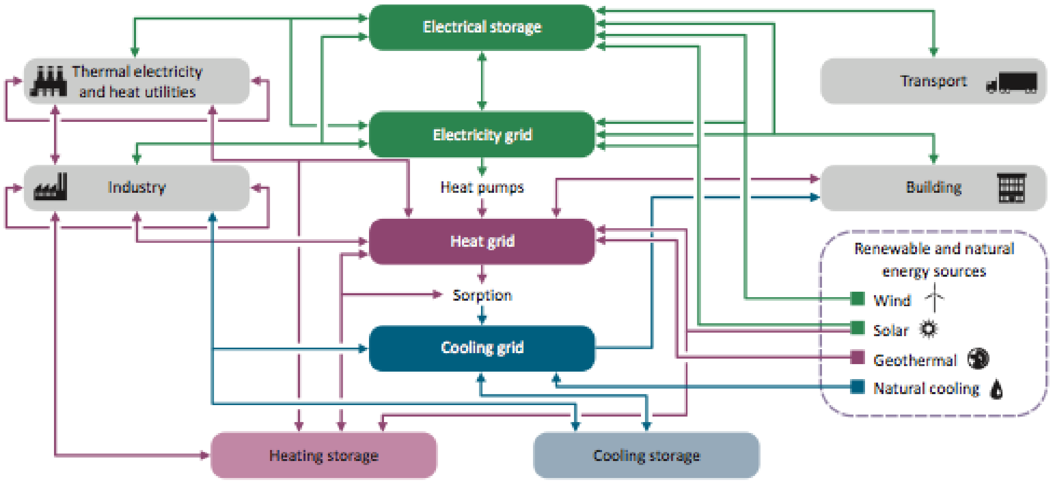
Intergovernmental Panel on Climate Change, *IPCC Fourth Assessment Report: Climate Change 2007*, online: <https://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch4s4-3-5.html>.

Exhibit “I”



International District Energy Association, *What is District Energy?*, online: <http://www.districtenergy.org/what-is-district-energy/>.

Exhibit “J”



Key point • Electricity and thermal energy systems are complex and offer numerous opportunities for deep integration.

International Energy Agency, *Linking Heat and Electricity Systems*, online: <https://www.iea.org/publications/freepublications/publication/LinkingHeatandElectricitySystems.pdf>.

Exhibit "K"

Technology Roadmap

Energy storage

International
Energy Agency

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency
1974•2014
Secure • Sustainable • Together

International Energy Agency
9 rue de la Fédération
75739 Paris Cedex 15, France

www.iea.org

Foreword

Current trends in energy supply and use are patently unsustainable – economically, environmentally and socially. Without decisive action, energy-related emissions of carbon dioxide (CO_2) will more than double by 2050 and increased fossil energy demand will heighten concerns over the security of supplies. We can and must change our current path, but this will take an energy revolution; and low-carbon energy technologies will have a crucial role to play. Energy efficiency, many types of renewable energy, carbon capture and storage (CCS), nuclear power and new transport technologies will all require widespread deployment if we are to sharply reduce greenhouse gas (GHG) emissions. Every major country and sector of the economy must be involved. The task is urgent if we are to make sure that investment decisions taken now do not saddle us with sub-optimal technologies in the long term.

Awareness is growing on the need to turn political statements and analytical work into concrete action. To spark this movement, at the request of the G8 nations, the International Energy Agency (IEA) is leading the development of a series of roadmaps for some of the most important technologies. By identifying the steps needed to accelerate the implementation of radical technology changes, these roadmaps will enable governments, industry and financial partners to make the right choices – and in turn help societies to make the right decisions.

Energy storage technologies can support energy security and climate change goals by providing valuable services in developed and developing energy systems. A systems approach to energy system design will lead to more integrated and optimised energy systems. Energy storage technologies can help to better integrate our electricity and heat systems and can play a crucial role in energy system decarbonisation by:

- improving energy system resource use efficiency
- helping to integrate higher levels of variable renewable resources and end-use sector electrification
- supporting greater production of energy where it is consumed
- increasing energy access
- improving electricity grid stability, flexibility, reliability and resilience.

While some energy storage technologies are mature or near maturity, most are still in the early stages of development and currently struggle to compete with other non-storage technologies due to high costs. They will require additional attention before their potential can be fully realised. Governments can help accelerate the development and deployment of energy storage technologies by supporting targeted demonstration projects for promising storage technologies and by eliminating price distortions that prevent storage technologies from being compensated for the suite of services they provide. Energy storage technologies have the potential to support our energy system's evolution, but realising this potential will require government, industry, academia and financial stakeholders to work together to help overcome existing barriers.

This publication is produced under my authority as Executive Director of the IEA.

Maria van der Hoeven
Executive Director
International Energy Agency

Table of contents

List of figures

List of tables

List of boxes

Acknowledgements

The International Energy Agency's Energy Technology Policy Division prepared this publication. Melissa C. Lott is the primary author of this roadmap together with contributions from Sang-Il Kim. Cecilia Tam, co-ordinator of the Energy Technology Roadmaps programme, was responsible for the development of this roadmap and provided valuable leadership throughout. Didier Houssin, Director of the Directorate of Sustainable Energy Policy and Technology and Jean-François Gagné, Head of the Energy Technology Policy Division, provided important guidance and input. David Elzinga, Steve Heinen, Luis Munuera and Uwe Remme provided significant input and support.

Many other IEA colleagues provided thoughtful comments and support including Marco Baroni, Doug Cooke, Alex Körner, Simone Landolina, Simon Müller, Edoardo Patriarca, Cédric Philibert, Alvaro Portellano, Yuan Qin, Katrin Schaber, Tali Trigg, Laszlo Varro and Dennis Volk. Hanneke van Kleeff and Katerina Rus helped to prepare the manuscript.

This work was developed in collaboration with governments, industry, experts, and the IEA energy technology network. The roadmap was supported by the Japanese Ministry of Economy, Trade, and Industry (METI), Korea Power Exchange (KPX), US Department of Energy (US DOE), GO15 – Reliable and Sustainable Power Grids, and the Implementing Agreement for a Programme of Research and Development on Energy Conservation through Energy Storage (ECES IA).

The volunteers of the energy storage roadmap steering committee have provided guidance over the course of its development: Halime Ö. Paksoy and Christian Doetsch (ECES IA); Yeoungjin Chae (KPX); Imre Gyuk (US DOE); Rao Konidena and Scott Baker (GO15); Gunter Siddiqi (Bundesamt für Energie); Anthony Vassallo (The University of Sydney); Yo Mishima, Eiko Nakayama, Tutsuya Tomida, Tatsuya Miyazaki, and Kelichi Onozawa (METI); Per-Olof Granstrom and Joris Knigge (EDSO).

Finally, the IEA would like to thank the numerous experts who provided the authors with information and/or comments on drafts of the roadmap and Technology Annex: Jianhua Bai, Mark Barrett, Brahim Betraoui, Luisa F. Cabeza, John Cheng, Benoit Decourt, Paul Denholm, Paul Dodds, Jean-Michel Durand, Robert Fares, Jared Garrison, Marco Gazzino, Frederik Geth, Logan Goldie-Scot, Naoki Hara, Jennifer Hiscock, Arne Höll, Mark Howells, Andreas Hauer, Sylvain Hercberg, Magnus Hindsberger, Takao Ikeda, Jens Kühne, Chuck Levitan, Francis Li, Liam Lidstone, Jun Liu, Vincent Mazauric, Stephen Orita, Anthony Price, Peter Schossig, Yoshiaki Shibata, Axel Strang, Peter Taylor, Yuriko Terao, Manuel Welsch, Mike Wilks, Kendra Wong, Hendrik Wust, Shicong Zhang and Andreas Zucker. The IEA would like to acknowledge the large number of participants and contributions made by attendees of the three workshops held at the IEA who are too numerous to be named individually.

The authors would also like to thank Kristine Douaud for editing the manuscript a well as the IEA publication unit, in particular Muriel Custodio, Astrid Dumond, Rebecca Gaghen, Cheryl Haines and Bertrand Sadin for their assistance in layout and graphical design support.

For more information on this document, contact:
TechnologyRoadmapsContact@iea.org

Key findings and actions

Key findings

- Energy storage technologies include a large set of centralised and distributed designs that are capable of supplying an array of services to the energy system. Storage is one of a number of key technologies that can support decarbonisation.
- Energy storage technologies are valuable in most energy systems, with or without high levels of variable renewable generation. Today, some smaller-scale systems are cost competitive or nearly competitive in remote community and off-grid applications. Large-scale thermal storage technologies are competitive for meeting heating and cooling demand in many regions.
- Individual storage technologies often have the ability to supply multiple energy and power services. The optimal role for energy storage varies depending on the current energy system landscape and future developments particular to each region.
- To support electricity sector decarbonisation in the *ETP 2014* 2DS, an estimated 310 GW of additional grid-connected electricity storage capacity would be needed in the United States, Europe, China and India. Significant thermal energy storage and off-grid electricity storage potential also exists. Additional data are required to provide a more comprehensive assessment and should be prioritised at the national level.
- Market design is key to accelerating deployment. Current policy environments and market conditions often cloud the cost of energy services, creating significant price distortions and resulting in markets that are ill-equipped to compensate energy storage technologies for the suite of services that they can provide.
- Public investment in energy storage research and development has led to significant cost reductions. However, additional efforts (e.g. targeted research and development investments and demonstration projects) are needed to further decrease energy storage costs and accelerate development.
- Thermal energy storage systems appear well-positioned to reduce the amount of heat that is currently wasted in the energy system. This waste heat is an underutilised resource, in part because the quantity and quality of both heat resources and demand is not fully known.

Key actions for the next ten years

- Determine where near-term cost effective niche markets exist and support deployment in these areas, sharing lessons learned to support long term development.
- Incentivise the retrofit of existing storage facilities to improve efficiency and flexibility.
- Develop marketplaces and regulatory environments that enable accelerated deployment, in part through eliminating price distortions and enabling benefits-stacking for energy storage systems, allowing these technologies to be compensated for providing multiple services over their lifetime.
- Support targeted demonstration projects for more mature, but not yet widely deployed, energy storage technologies to document system performance and safety ratings. Share information collected including lessons learned widely through storage stakeholder groups.
- Support investments in research and development for early stage energy storage technologies including technology breakthroughs in high-temperature thermal storage systems and scalable battery technologies, and systems that incorporate the use of both electricity and thermal energy storage (i.e. hybrid systems) to maximise resource use efficiency.
- Establish a comprehensive set of international standards in a manner that allows for incremental revisions as energy storage technologies mature.
- Evaluate and broadly disseminate the learning and experience from established installations. Information should include data on both technical aspects (e.g. generation, cost, performance) and contextual details (e.g. market conditions, energy pricing structures) specific to a region/market.
- Establish international and national data co-operation to foster research, monitor progress and assess the research and development (R&D) bottlenecks. Complete analysis in support of regional assessments to quantify the value of energy storage in specific regions and energy markets, and promote the development and adoption of tools devoted to evaluating energy storage project proposals.

Introduction

Energy storage technologies absorb energy and store it for a period of time before releasing it to supply energy or power services. Through this process, storage technologies can bridge temporal and (when coupled with other energy infrastructure components) geographical gaps between energy supply and demand. Energy storage technologies can be implemented on large and small scales in distributed and centralised manners throughout the energy system. While some technologies are mature or near maturity, most are still in the early stages of development and will require additional attention before their potential can be fully realised.

In this roadmap, energy storage technologies are categorised by output: **electricity** and **thermal** (heat or cold).[1] Technologies in both categories can serve as generators and consumers, giving them the potential to link currently disconnected energy markets (e.g. power, transportation fuels, and local heat markets). Broadly speaking, energy storage is a system integration technology that allows for the improved management of energy supply and demand. In many cases, a single unit of energy storage infrastructure can provide multiple valuable energy and power services.

This roadmap aims to increase understanding among a range of stakeholders of the applications that electricity and thermal energy storage technologies can be used for at different locations in the energy system.[2] Emphasis is placed on storage technologies that are connected to a larger energy system (e.g. electricity grid), while a smaller portion of the discussion focuses on off-grid storage applications. This focus is complemented by a discussion of the existing technology, policy, and economic barriers that hinder energy storage deployment. Specific actions that can be taken to remove these obstacles are identified for key energy system stakeholder groups.

Rationale for energy storage

Energy storage technologies are valuable components in most energy systems and could be an important tool in achieving a low-carbon future. These technologies allow for the decoupling of energy supply and demand, in essence providing a valuable resource to system operators. There are many cases where energy storage deployment is competitive or near-competitive in today's energy system. However, regulatory and market conditions are frequently ill-equipped to compensate storage for the suite of services that it can provide. Furthermore, some technologies are still too expensive relative to other competing technologies (e.g. flexible generation and new transmission lines in electricity systems).

Historically, storage technologies were predominantly installed as an investment that could take advantage of dispatchable supply resources and variable demand. Today, increasing emphasis on energy system decarbonisation has drawn awareness to the ability for storage technologies to increase resource use efficiency (e.g. using waste heat through thermal storage technologies) and to support increasing use of variable renewable energy supply resources. Moving forward, it is important that energy storage be considered from a systems point of view with a focus on the multiple services that it can provide in bulk, small-scale (e.g. off-grid) and other applications.

R&D work is currently underway with the primary goals of realising technology cost reductions and improving the performance of existing, new and emerging storage technologies. Furthermore, many government and industry stakeholders are identifying and attempting to address non-technical barriers to deployment. Looking forward, the most important drivers for increasing use of energy storage will be:

- improving energy system resource use efficiency
- increasing use of variable renewable resources
- rising self-consumption and self-production of energy (electricity, heat/cold)
- increasing energy access (e.g. via off-grid electrification using solar photovoltaic (PV) technologies)
- growing emphasis on electricity grid stability, reliability and resilience
- increasing end-use sector electrification (e.g. electrification of transport sector).

1. Chemical (hydrogen) storage and fuel cell technologies are not included.

2. "Locations" refers to the supply, transmission and distribution, and demand portions of the energy system.

Purpose, process and structure of the roadmap

This energy storage roadmap aims to:

- increase understanding among a range of stakeholders of the applications that electricity and thermal energy storage technologies can be used for at different locations in the energy system
- provide a comprehensive discussion of the nature, function, and costs of energy storage technologies
- identify the most important actions required in the short and long terms to successfully develop and deploy energy storage technologies to support global energy and climate goals
- articulate actions to support progress toward short- (next 10 years) and long-term (by 2050) goals.

This roadmap was compiled with the support of a wide range of interested parties and stakeholders, including members of industry, academia, consumer advocacy groups, and government institutions. In parallel with its analysis and modelling efforts, the energy storage roadmap team hosted three expert workshops (Table 1).

Table 1: Workshop contributions to the energy storage roadmap

Date	*Workshop focus*
23 January 2013	International Energy Agency (IEA) Global Dispatch Model: the integration of energy storage
13-14 February 2013	Energy storage technology roadmap stakeholder engagement: scope and technology discussion
23-24 September 2013	Energy storage technology roadmap second stakeholder engagement: policy, markets, and finance discussions

Source: unless otherwise indicated, all material in tables and figures derives from IEA data and analysis.

Roadmap scope

The value of energy storage technologies lies in the services that they provide at different locations in the energy system, including heat to heat, electricity to electricity, electricity to heat, and heat to electricity applications. This roadmap therefore includes discussion of storage technologies in the context of these applications. Locations in the energy system are termed as generation (supply), transmission and distribution, and end-use (demand).

The focus of the vision presented in this roadmap is centred on the IEA *Energy Technology Perspectives 2014* (*ETP 2014*) 2°C Scenario (2DS) vision for energy storage. In *ETP 2014*, a chapter is dedicated to discussion of electricity storage technologies as flexibility and system integration resources in the electricity system. Due to modelling limitations, this section in the roadmap provides quantitative detail for only a portion of the potential role for energy storage in the 2050 energy system. However, the actions recommended in this roadmap extend beyond this vision and focus on a more holistic approach to advancing and deploying these technologies.

Discussion, case studies, and boxes are included in this roadmap for electricity and thermal storage technologies. As a complement to this roadmap, the IEA has also developed an Energy Storage Technology Annex, which includes further details and numerous project examples for electricity and thermal storage technologies.[3]

This is the first IEA technology roadmap that focuses solely on energy storage technologies. Previous IEA publications have included discussion on storage technologies as energy system support mechanisms, including roadmaps dedicated to

3. See www.iea.org/publications/freepublications/publication/name,36573,en.html

the smart grid, heating and cooling equipment for buildings, hydropower, and concentrating solar power (solar thermal electricity generation). Existing IEA projects, such as Grid Integration of Variable Renewables (GIVAR)[4], have focused on the flexibility needs of specific electricity grid systems around the world. What's more, the IEA Implementing Agreement (IA) for a Programme of R&D on Energy Conservation through Energy Storage (ECES) and the IA for Programme of Energy Technology Systems Analysis (ETSAP) have recently published several publications specifically discussing energy storage technologies, and opportunities for implementation as a part of their ongoing work in this area.[5]

This roadmap responds to requests for deeper analysis on the role that energy storage technologies can play in the decarbonisation of global energy systems. It should be considered a work in progress and a starting point for discussions. As global datasets and corresponding analysis improve, scenarios and insights will evolve. Furthermore, as technology, market, and policy environments shift, additional requirements and areas for analysis and attention will come to light.

4. See www.iea.org/topics/renewables/givar/for more details on this project.

5. See the ECES www.iea-eces.org/ and ETSAP www.iea-etsap.org websites for more information.

Energy storage applications

The value of energy storage technologies is found in the services that they provide at different locations in the energy system. These technologies can be used throughout the electricity grid, in dedicated heating and cooling networks, and in distributed system and off-grid applications. Furthermore, they can provide infrastructure support services across supply, transmission and distribution, and demand portions of the energy system. Broadly speaking, they can serve as valuable tools for operators in systems with supply and/or demand-side variability. The latter has historically been part of the energy system. The former is an increasing concern in a transition to increased penetration of variable renewables. Some typical energy storage technology applications are listed below in Table 2.

Table 2: Key characteristics of storage systems for particular applications in the energy system

Application	Output (electricity, thermal)	Size (MW)	Discharge duration	Cycles (typical)	Response time
Seasonal storage	e,t	500 to 2 000	Days to months	1 to 5 per year	day
Arbitrage	e	100 to 2 000	8 hours to 24 hours	0.25 to 1 per day	>1 hour
Frequency regulation	e	1 to 2 000	1 minute to 15 minutes	20 to 40 per day	1min
Load following	e,t	1 to 2 000	15 minutes to 1 day	1 to 29 per day	<15min
Voltage support	e	1 to 40	1 second to 1 minute	10 to 100 per day	millisecond to second
Black start	e	0.1 to 400	1 hour to 4 hours	< 1 per year	<1 hour
Transmission and Distribution (T&D) congestion relief	e,t	10 to 500	2 hours to 4 hours	0.14 to 1.25 per day	>1hour
T&D infrastructure investment deferral	e,t	1 to 500	2 hours to 5 hours	0.75 to 1.25 per day	>1hour
Demand shifting and peak reduction	e,t	0.001 to 1	Minutes to hours	1 to 29 per day	<15 min
Off-grid	e,t	0.001 to 0.01	3 hours to 5 hours	0.75 to 1.5 per day	<1hour
Variable supply resource integration	e,t	1 to 400	1 minute to hours	0.5 to 2 per day	<15 min
Waste heat utilisation	t	1 to 10	1 hour to 1 day	1 to 20 per day	< 10 min
Combined heat and power	t	1 to 5	Minutes to hours	1 to 10 per day	< 15 min
Spinning reserve	e	10 to 2 000	15 minutes to 2 hours	0.5 to 2 per day	<15 min
Non-spinning reserve	e	10 to 2 000	15 minutes to 2 hours	0.5 to 2 per day	<15 min

Sources: IEA (2014a), *Energy Technology Perspectives,* forthcoming, OECD/IEA, Paris, France. EPRI (Electric Power Research Institute) (2010), "Electrical Energy Storage Technology Options", Report, EPRI, Palo Alto, California. Black & Veatch (2012), "Cost and performance data for power generation technologies", *Cost Report*, Black & Veatch, February.

Box 1: Energy versus power applications for electricity storage technologies

Applications for electricity storage technologies can be discussed in terms of power applications versus energy applications. Power applications refer to those requiring a high power output for a relatively short period of time (e.g. seconds or minutes). Energy applications require discharge of many minutes to several hours at or near the storage system's nominal power rating.

Key application definitions

Seasonal storage

The ability to store energy for days, weeks, or months to compensate for a longer-term supply disruption or seasonal variability on the supply and demand sides of the energy system (e.g. storing heat in the summer to use in the winter via underground thermal energy storage systems).

Arbitrage/Storage trades

Storing low-priced energy during periods of low demand and subsequently selling it during high-priced periods within the same market is referred to as a storage trade.[6] Similarly, arbitrage refers to this type of energy trade between two energy markets.

Frequency regulation

The balancing of continuously shifting supply and demand within a control area under normal conditions is referred to as frequency regulation. Management is frequently done automatically, on a minute-to-minute (or shorter) basis.

Load following

The second continuous electricity balancing mechanism for operation under normal conditions, following frequency regulation, is load following. Load following manages system fluctuations on a time frame that can range from 15 minutes to 24 hours, and can be controlled through automatic generation control, or manually.

Voltage support

The injection or absorption of reactive power to maintain voltage levels in the transmission and distribution system under normal conditions is referred to as voltage support.

Black start

In the rare situation when the power system collapses and all other ancillary mechanisms have failed, black start capabilities allow electricity supply resources to restart without pulling electricity from the grid.

T&D congestion relief and infrastructure investment deferral

Energy storage technologies use to temporally and/or geographically shifting energy supply or demand in order to relieve congestion points in the transmission and distribution (T&D) grids or to defer the need for a large investment in T&D infrastructure.

Demand shifting and peak reduction

Energy demand can be shifted in order to match it with supply and to assist in the integration of variable supply resources. These shifts are facilitated by changing the time at which certain activities take place (e.g. the heating of water or space) and can be directly used to actively facilitate a reduction in the maximum (peak) energy demand level.

Off-grid

Off-grid energy consumers frequently rely on fossil or renewable resources (including variable renewables) to provide heat and electricity.[7]
To ensure reliable off-grid energy supplies and to support increasing levels of local resources use, energy storage can be used to fill gaps between variable supply resources and demand.

6. The term "arbitrage" is used for both arbitrage and storage trades in this roadmap.

7. This is also the case for energy users who produce most of their own heat and electricity (i.e. self-generation).

Variable supply resource integration

The use of energy storage to change and optimise the output from variable supply resources (e.g. wind, solar), mitigating rapid and seasonal output changes and bridging both temporal and geographic gaps[8] between supply and demand in order to increase supply quality and value.

Waste heat utilisation

Energy storage technology use for the temporal and geographic decoupling of heat supply (e.g. CHP facilities, thermal power plants) and demand (e.g. for heating/cooling buildings, supplying industrial process heat) in order to utilise previously wasted heat.

8. When combined with other energy system infrastructure (e.g. transmission lines).

Combined heat and power

Electricity and thermal energy storage can be used in combined heat and power (CHP) facilities in order to bridge temporal gaps between electricity and thermal demand.

Spinning and non-spinning reserve

Reserve capacity for the electricity supply is used to compensate for a rapid, unexpected loss in generation resources in order to keep the system balanced. This reserve capacity is classified according to response time as spinning (<15 minute response time) and non-spinning (>15 minute response time). Faster response times are generally more valuable to the system. In some regions, reserve capacity is referred to as "frequency containment reserve."

Box 2: Potential use of thermal storage in CHP plants to support the integration of renewable energy resources

Thermal energy storage can increase operational flexibility in CHP plants by enabling the decoupling of the heat demand of a connected district heating system and the requirements of the electricity system. Furthermore, the increased flexibility afforded by both thermal and electricity storage in CHP facilities could enable higher levels of participation in balancing power markets.

Thermal storage, in the context of district heating, stores heat in the form of hot water in tanks. In atmospheric storage systems, the water temperature lies just below the boiling point at around 95°C to 98°C. Pressurised tanks typically store water at temperatures of between 120°C and 130°C. The size of such storage tanks can range from 100 cubic metres (m^3) up to 50 000 m^3 in volume, which corresponds to heat storage capacities from approximately 10 megawatt hours (MWh) to 2 gigawatt hours (GWh) per load cycle.

Storage facilities that store energy at atmospheric pressure have comparatively lower investment costs than pressurised ones. However, the pressurised storage technologies show a 30% to 40% higher specific storage capacity per volume.

Today's thermal storage facilities focus on reducing the operation of peak load boilers and avoiding costly restarting processes. Furthermore, in the presence of district heating networks, heat price can have a significant impact on the choice of the CHP plant's business model. In the case of rapidly increasing use of renewable energy resources, CHP is poised to operate primarily in one of two strategies.

(.../...)

Box 2: Potential use of thermal storage in CHP plants to support the integration of renewable energy resources (continued)

Case A High electricity prices	Case B Low electricity prices
High residual load*	***Low or negative residual load***
Focus placed primarily on electricity production with residual heat being directed to district heating networks as it is available. The balance of the heat demand is met using previously charged thermal storage systems or other heat-only facilities. *However, in many CHP facilities, heat and electricity production are coupled in a rigid manner. As a result, medium or low heat demand results in decreased levels of electricity production. In this case, thermal storage can serve as the heat sink to allow for increased electricity production at times of low heat demand (and vice versa).*	*In this case, the electricity price is lower than the electricity production costs of the CHP plant. As a result, the CHP is either shut down or operated at the minimum level needed to prevent shutdown and any heat demand is served by previously charged thermal storage.* *In these cases, CHP facilities could alternatively integrate auxiliary electric heating systems (power-to-heat) if no higher-value application exists for the electricity. The combination of CHP plants, thermal storage and power-to-heat systems allows for the direct integration of excess electricity from renewable energy sources into district heating networks.*

* Residual load is defined as the electricity demand minus the amount supplied by renewable energy.

Benefits-stacking

The ability for a technology or system to receive revenue from providing multiple compatible applications is referred to as "benefits-stacking" and is critical in the value proposition for many energy storage technologies. Compatibility is measured in terms of a technology's ability to technically provide and operationally manage the applications included in the benefits stack.

Box 3: The impacts of US Federal Energy Regulatory Commission Orders 755 (2011) and 784 (2013) on energy storage deployment

In the electricity system, energy storage technologies have the ability to provide value via multiple applications. For example, a system might be able to provide energy supply and demand management services (i.e. where peak demand for electricity or heat is reduced to relieve supply pressures, or supply availability is time-shifted to better match demand profiles) and also be used in power applications (e.g. fast response, frequency regulation, voltage support).

However, in order to maintain the independence and neutrality of transmission grid operators and to avoid market manipulation, US energy market rules generally prohibit transmission assets from participating in wholesale energy and ancillary service markets. This distinction between transmission and generation assets results in unintended negative consequences for energy storage technologies that can supply services in both the transmission and generation portions of the energy system. As a result, the US Federal Energy Regulatory Commission (FERC) has needed to approve the classification of certain storage assets on a case-by-case basis (e.g. the 2010 installation of a sodium-sulphur (NaS) battery system owned by Electric Transmission Texas in Presidio, Texas)

(…/…)

Box 3: The impacts of US Federal Energy Regulatory Commission Orders 755 (2011) and 784 (2013) on energy storage deployment (continued)

Recognising these challenges, the US FERC has recently made significant strides in amending market rules and tariff structures to allow energy storage technologies to receive compensation for supplying energy services across the energy system. Specifically, FERC Order 890 and 719 asked the nation's independent system operators (ISOs) to allow all non-generating resources – such as demand response and energy storage technologies – to fully participate in established energy markets.

Subsequently, under FERC order 755, the Commission recognised the added value found in "fast" responding resources (e.g. batteries, flywheels) for frequency regulation applications. This order acknowledged the added value that these technologies bring to the energy system compared to slower-responding technologies. This pay-for-performance requirement was subsequently expanded upon in FERC Order 784, which not only addresses speed and accuracy requirement questions, but also more broadly opens ancillary service markets to energy storage technology participation.

Today, many organisations including the Pennsylvania-New Jersey-Maryland (PJM) Interconnection, a regional transmission organisation (RTO) in the United States' eastern grid interconnection, have expanded their activities in bringing new energy storage systems online (Table 3).

Table 3: Energy storage technologies and intended applications in United States PJM market

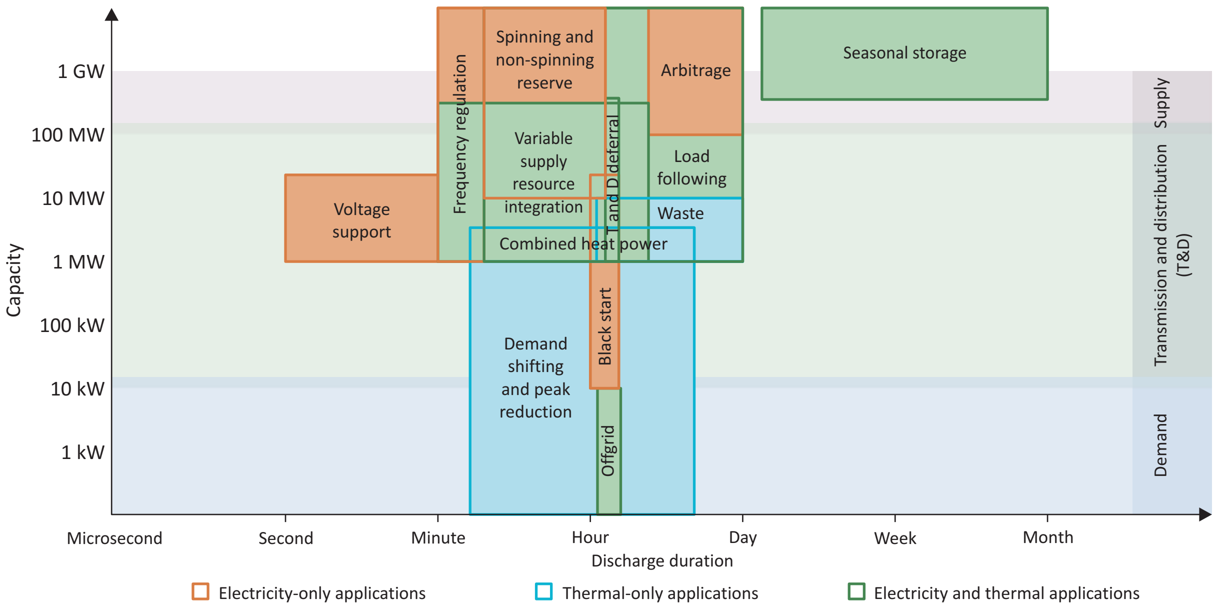
Storage technology	*Facility size*	*PJM installed resource or in planning queue*	*Typical discharge time*	*Potential grid application(s)*
Pumped-storage hydropower	Up to 3.1 GW	Muddy Run, Seneca Yards Creek, Bath County, Smith Mountain	7 hours to 13+ hours	Energy and power applications
Batteries (flow, lead-acid, Li-ion, sodium-sulphur)	0.5-20 MW	Ironwood Project (20 MW, in queue), 1 MW Li-ion (in service), 2 MW battery storage (in queue)	1 hour to 6 hours	Energy and power applications
Flywheel		Beacon (20 MW)	<2 hours	Energy and power applications

Source: Pennsylvania-New Jersey-Maryland (PJM) Interconnection (2010), "Limited energy resources in capacity markets: problem statement", paper prepared for August 5 meeting, Audubon, PA, United States, www.pjm.com/~/media/committees-groups/committees/mrc/20100805/20100805-item-10b-limited-energy-resources.ashx.

The suitability of a particular technology for an individual application can be broadly evaluated in terms of technical potential. For electricity storage, discharge period, response time and power rating provide a good first indicator on suitability. For thermal storage, storage output temperature and capacity can be used as a starting point in determining suitability for particular applications (Hauer, Quinnell and Lävemann, 2013). In Figure 1, power requirements are plotted in relationship with energy requirements to illustrate the combinations that are most suited to certain applications.

Near-term suitability could also be broadly determined by considering the characteristics of the current energy system, as shown in Table 4.

Figure 1: Power requirement versus discharge duration for some applications in today's energy system



Sources: modified from IEA (2014), Energy Technology Perspectives, OECD/IEA, Paris, France. Battke, B., T.S. Schmidt, D. Grosspietsch and V.H. Hoffmann (2013), "A review and probabilistic model of lifecycle costs of stationary batteries in multiple applications", *Renewable and Sustainable Energy Reviews* Vol. 25, pp. 240-250. EPRI (Electric Power Research Institute) (2010), "Electrical Energy Storage Technology Options", Report, EPRI, Palo Alto, CA, United States. Sandia National Laboratories (2010), *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide, A Study for the DOE Energy Storage Systems*, Albuquerque, NM and Livermore, CA, United States. IEA-ETSAP (Energy Technology Systems Analysis Programme) and IRENA (2013), "Thermal Energy Storage", Technology Brief E17, Bonn, Germany.

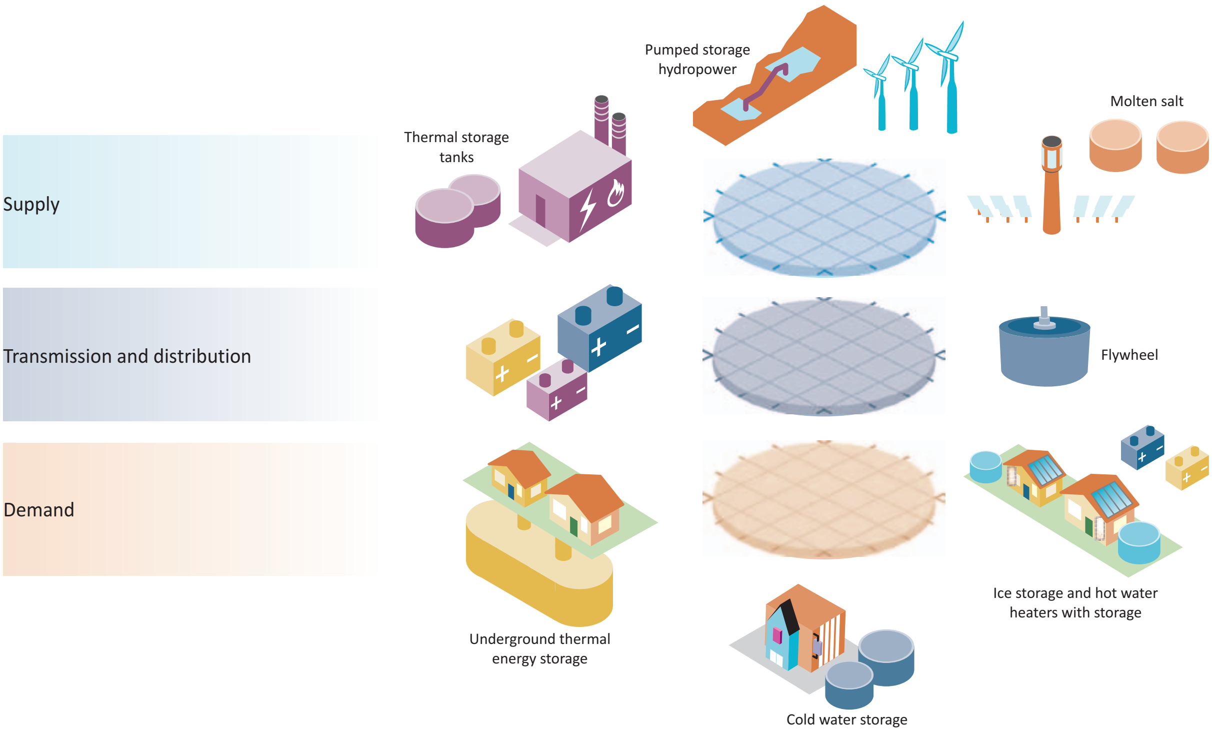
Table 4: Near-term suitability criteria for determining prime energy storage technologies for deployment

Energy storage technology	*Technology examples*	*Might provide the most near-term benefits in areas with:*
Large-scale electricity	pumped-storage hydropower (PSH), compressed air energy storage (CAES), flywheels	developed electricity grids that can more easily accommodate centralised energy supply resources
Large-scale thermal	underground thermal energy storage (UTES), molten salts	significant waste heat resources, concentrated heating or cooling demand, or large amounts of concentrating solar power (CSP)
Small-scale electricity	batteries	remote and off-grid communities as well as those looking to diversify their transportation fuel resource demand
Small-scale thermal	ice storage, hot and cold-water tanks	higher demand variability (i.e. more "peak-y" demand – lots of hot or cold needed at one time or another)

Locations

Energy storage deployment could be realised across the supply, transmission and distribution, and demand (end-use) portions of the energy system (Figure 2). The best location for individual storage technology deployment depends on the services these technologies will supply to specific locations in the energy system. Furthermore, the introduction of the smart grid and other new energy infrastructure technologies could impact the optimal location for storage technologies in the future. The hypothetical storage deployment shown in Figure 2 illustrates the widespread deployment of a diverse set of storage technologies across the electric power system. This example includes deployment across the supply, transmission and distribution, and demand portions of the grid, with varying scales and types of storage.

Figure 2: Hypothetical deployment of storage assets across an electric power system



Source: modified from EIA (Energy Information Administration) (2012), "Electricity storage: Location, location, location.....and cost", *Today in Energy*, Washington, DC, United States, www.eia.gov/todayinenergy/detail.cfm?id=6910.

Status of energy storage technologies today

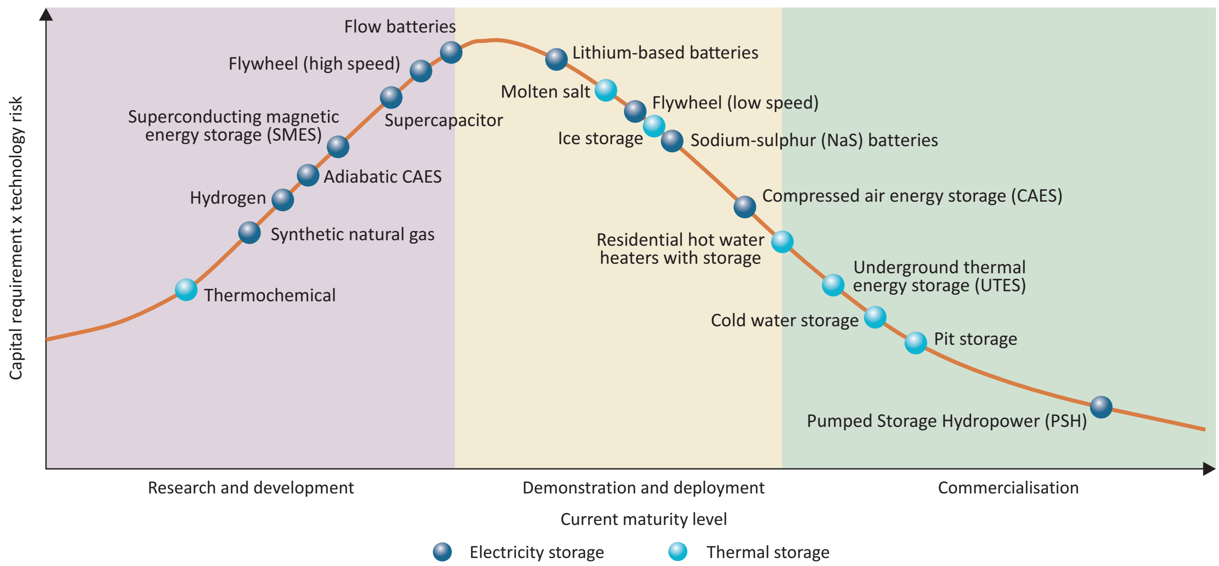
This roadmap defines energy storage technologies in terms of output – **electricity** versus **thermal** (heat or cold).[9] Today, electricity and thermal storage technologies exist at many levels of development, from the early stages of R&D to mature, deployed technologies.[10] The IEA *Technology Roadmap: Energy Storage* Technology Annex includes in-depth descriptions and project examples for many energy storage technologies. In Figure 3, some key technologies are displayed with respect to their associated initial capital investment requirements and technology risk versus their current phase of development (i.e. R&D, demonstration and deployment, or commercialisation phases).[11]

9. Hydrogen storage is the subject of the forthcoming IEA technology roadmap on hydrogen storage and so will not be covered in detail here.

10. This development spectrum is roughly equivalent to the concepts of "Technology Readiness Levels" (TRLs) and Manufacturing Readiness Levels (MRLs).

11. For the sake of concision, only a limited number of energy storage technologies are included in Figure 3. This list is not meant to be comprehensive, but to highlight some of the promising and successfully deployed technologies in the energy system.

Figure 3: Maturity of energy storage technologies



Source: Decourt, B. and R. Debarre (2013), "Electricity storage", *Factbook*, Schlumberger Business Consulting Energy Institute, Paris, France and Paksoy, H. (2013), "Thermal Energy Storage Today" presented at the IEA Energy Storage Technology Roadmap Stakeholder Engagement Workshop, Paris, France, 14 February.

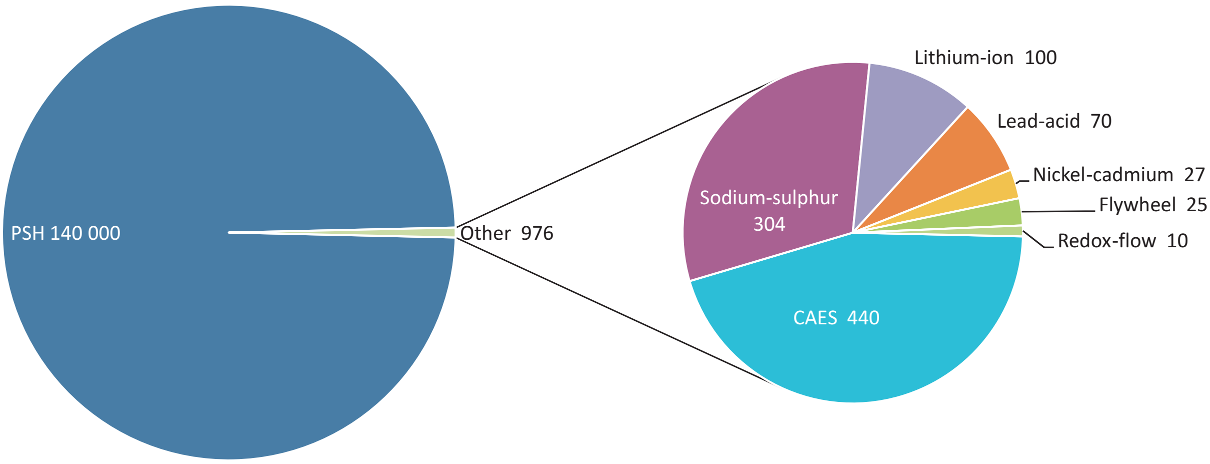
Current installed capacity

While some datasets exist that quantify the storage capabilities found in today's energy systems, attempts to comprehensively summarise the current global installed capacity for energy storage struggle from a lack of widespread and accessible data as well as conflicting definitions regarding what should be included in the baseline.

Today, it is somewhat easier to establish a baseline for some countries, including the United States and Japan as well as some regions in Europe, for a specific subset of energy storage technologies. In these cases, data can be found for large-scale, grid-connected electricity storage systems. These data reveal that at least 140 gigawatts (GW) of large-scale energy storage is currently installed in electricity grids worldwide. The vast majority (99%) of this capacity is comprised of PSH technologies (Figure 4). The other 1% includes a mix of battery, CAES, flywheels, and hydrogen storage (Ying, 2011; US DOE, 2013).

Remaining data gaps challenge attempts to establish a reliable baseline for current installed capacity and work in analysing future potential for both connected and off-grid systems. The potential of distributed energy storage in existing infrastructure has not yet been evaluated; however, the ECES IA recently started a new activity on this topic (Annex 28, "Integration of Renewable Energy by Distributed Energy Storage").

Figure 4: Current global installed grid-connected electricity storage capacity (MW)



Source: IEA analysis and EPRI (Electric Power Research Institute) (2010), "Electrical Energy Storage Technology Options", Report, EPRI, Palo Alto, California.

For thermal energy storage, one of the most common technologies installed today is domestic hot water tanks. Other technologies, such as ice and chilled water storage, play an important role in in several countries, including Australia, the United States, China and Japan, as utilities seek to reduce peak loads and consumers seek to lower their electricity bills. Underground thermal energy storage (UTES) systems are frequently found in Canada, Germany, and many other European countries (IEA, 2011).

Table 5: Estimated thermal energy storage capacity in the United States in 2011

Technology type (application)	*Units (MW) in 2011*
Ice storage (commercial buildings and district cooling)	1 000
Cold-water storage (district cooling)	355
Electric thermal storage (heating)	1 000

Source: O'Donnell, A. and K-A. Adamson (2012), "Thermal Storage for HVAC in Commercial buildings, District Cooling and Heating, Utility and Grid Support Applications, and High-Temperature Storage at CSP Facilities", Pike Research, New York.

Brief technology descriptions and examples of existing projects for both thermal and electricity storage technologies can be found in the IEA Energy Storage Technology Annex. Table 6 depicts a range of energy storage technologies in terms of several technology characteristics. As these technologies cannot store and discharge energy without losses efficiency values are included in this table.

Table 6: Energy storage technologies: current status and typical locations in today's energy system*

Technology	Location*	Output	Efficiency (%)	Initial investment cost (USD/kW)	Primary application	Example projects
PSH	Supply	Electricity	50 - 85	500 - 4 600	Long-term storage	Goldisthal Project (Germany), Okinawa Yanbaru Seawater PSH Facility (Japan), Pedreira PSH Station (Brazil)
UTES	Supply	Thermal	50 - 90	3 400 - 4 500	Long-term storage	Drake Landing Solar Community (Canada), Akershus University Hospital and Nydalen Industrial Park (Norway)
CAES	Supply	Electricity	27 - 70	500 - 1 500	Long-term storage, arbitrage	McIntosh (Alabama, United States), Huntorf (Germany)
Pit storage	Supply	Thermal	50 - 90	100 - 300	Medium temperature applications	Marstal district heating system (Denmark)
Molten salts	Supply	Thermal	40 - 93	400 - 700	High-temperature applications	Gemasolar CSP Plant (Spain)
Batteries	Supply, demand	Electricity	75 - 95	300 - 3 500	Distributed/ off-grid storage, short-term storage	NaS batteries (Presidio, Texas, United States and Rokkasho Futamata Project, Japan), Vanadium redox flow (Sumimtomo's Densetsu Office, Japan), Lead-acid (Notrees Wind Storage Demonstration Project, United States), Li-ion (AES Laurel Mountain, United States), Lithium Polymer (Autolib, France)

Table 6: Energy storage technologies: Current status and typical locations in today's energy system* (continued)

Technology	Location*	Output	Efficiency (%)	Initial investment cost (USD/kW)	Primary application	Example projects
Thermochemical	Supply, demand	Thermal	80 - 99	1 000 - 3 000	Low, medium, and high-temperature applications	TCS for Concentrated Solar Power Plants (R&D)
Chemical-hydrogen storage	Supply, demand	Electrical	22 - 50	500 - 750	Long-term storage	Utsira Hydrogen Project (Norway), Energy Complementary Systems H2Herten (Germany)
Flywheels	T&D	Electricity	90 - 95	130 - 500	Short-term storage	PJM Project (United States)
Supercapacitors	T&D	Electricity	90 - 95	130 - 515	Short-term storage	Hybrid electric vehicles (R&D phase)
Superconducting magnetic energy storage (SMES)	T&D	Electricity	90 - 95	130 - 515	Short-term storage	D-SMES (United States)
Solid media storage	Demand	Thermal	50 - 90	500 - 3 000	Medium temperature applications	Residential electric thermal storage (USA)
Ice storage	Demand	Thermal	75 - 90	6 000 - 15 000	Low-temperature applications	Denki University (Tokyo, Japan) , China Pavilion project (China)
Hot water storage (residential)	Demand	Thermal	50 - 90	**	Medium temperature applications	Peak demand reduction (France), TCES (United States)
Cold-water storage	Demand	Thermal	50 - 90	300 - 600	Low-temperature applications	Shanghai Pudong International Airport (China)

Note: see IEA Energy Storage Technology Annex for more information. www.iea.org/publications/freepublications/publication/name,36573,en.html.

* Typical locations in today's energy system. These locations may change as the energy system evolves.

** Energy storage capabilities present in hot water storage tanks can be utilised for negligible additional cost.

Sources: IEA (2014a), *Energy Technology Perspectives,* forthcoming, OECD/IEA, Paris, France. IEA (2011), *Technology Roadmap: Energy Efficient Buildings: Heating and Cooling Equipment,* OECD/IEA, Paris, France. Black & Veatch (2012), "Cost and performance data for power generation technologies", *Cost Report*, Black & Veatch, February. EPRI (Electric Power Research Institute) (2010), "Electrical Energy Storage Technology Options", Report, EPRI, Palo Alto, California. Eyer, J. and G. Corey, (2010), "Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide", Sandia National Laboratory, Albuquerque, NM, United States. IEA-ETSAP and IRENA (2013), "Thermal Energy Storage" *Technology Brief E17,* Bonn, Germnay. IEA-ETSAP (Energy Technology Systems Analysis Programme) and IRENA (International Renewable Energy Agency) (2012), "Electricity Storage",*Technology Policy Brief E18,* Bonn, Germany. "Power Tower Technology Roadmap and Cost Reduction Plan", Sandia National Laboratories (2011), Albuquerque, NM and Livermore, CA, United States.

Box 4: Energy storage technology descriptions

Pumped storage hydropower (PSH) systems utilise elevation changes to store off-peak electricity for later use. Water is pumped from a lower reservoir to a reservoir at a higher elevation during off-peak periods. Subsequently, water is allowed to flow back down to the lower reservoir, generating electricity in a fashion similar to a conventional hydropower plant.

Underground thermal energy storage (UTES) systems pump heated or cooled water underground for later use as a heating or cooling resource. These systems include aquifer and borehole thermal energy storage systems, where this water is pumped into (and out of) either an existing aquifers or man-made boreholes.

Compressed air energy storage (CAES) systems use off-peak electricity to compress air, storing it in underground caverns or storage tanks. This air is later released to a combustor in a gas turbine to generate electricity during peak periods.

Pit storage systems use shallow pits, which are dug and filled with a storage medium (frequently gravel and water) and covered with a layer of insulating materials. Water is pumped into and out of these pits to provide a heating or cooling resource.

Molten salts are solid at room temperature and atmospheric pressure, but undergo a phase change when heated. This liquid salt is frequently used to store heat in CSP facilities for subsequent use in generating electricity.

Batteries use chemical reactions with two or more electrochemical cells to enable the flow of electrons. Examples include lithium-based batteries (ex: lithium-ion, lithium polymer), sodium sulphur, and lead-acid batteries.

Thermochemical storage uses reversible chemical reactions to store thermal energy in the form of chemical compounds. This energy can be discharged at different temperatures, dependent on the properties of the thermochemical reaction.

Chemical-hydrogen storage uses hydrogen as an energy carrier to store electricity, for example through electrolysis. Electricity is converted, stored, and then re-converted into the desired end-use form (e.g. electricity, heat, or liquid fuel).

Flywheels are mechanical devices that spin at high speeds, storing electricity as rotational energy. This energy is later released by slowing down the flywheel's rotor, releasing quick bursts of energy (i.e. releases of high power and short duration).

Supercapacitors store energy in large electrostatic fields between two conductive plates, which are separated by a small distance. Electricity can be quickly stored and released using this technology in order to produce short bursts of power.

Superconducting magnetic energy storage (SMES) systems store energy in a magnetic field. This field is created by the flow of direct current (DC) electricity into a super-cooled coil. In low-temperature superconducting materials, electric currents encounter almost no resistance, so they can cycle through the coil of superconducting wire for a long time without losing energy.

Solid media storage systems store energy in a solid material for later use in heating or cooling. In many countries, electric heaters include solid media storage (e.g. bricks or concrete) to assist in regulating heat demand.

Ice storage is a form of latent heat storage, where energy is stored in a material that undergoes a phase change as it stores and releases energy. A phase change refers to transition of a medium between solid, liquid, and gas states. This transition can occur in either direction (i.e. from a liquid to a solid or vice versa), depending on if energy is being stored or released.

Hot- and cold-water storage in tanks can be used to meet heating or cooling demand. A common example of hot water storage can be found in domestic hot water heaters, which frequently include storage in the form of insulated water tanks.

Electricity storage

Electricity storage technologies can be grouped into three main time categories (short-term, long-term and distributed battery storage) based on the types of services that they provide. Systems include a number of technologies in various stages of development. Broadly speaking, PSH, CAES, and some battery technologies are the most mature, while flow batteries, SMES, supercapacitors and other advanced battery technologies are currently at much earlier stages of development.

Major R&D efforts exist for many electricity storage technologies. In particular, battery and hydrogen technologies have received significant funding in support of research, development, and demonstration projects in regions including the United States, Japan, and Germany. The primary technology characteristics used in assessing a technology's potential for use in specific applications include storage and operation properties (including energy and power capacity, density, efficiency, scale, discharge capacity, response time, and lifetime or cycling performance), and cost (Inage 2009).

Short-term (seconds-minutes) storage applications

Supercapacitors and SMES technologies use static electric or magnetic fields to directly store electricity. Flywheels store and then release electricity from the grid by spinning and then applying torque to its rotor to slow rotation. These technologies generally have high cycle lives and power densities, but much lower energy densities. This makes them best suited for supplying short bursts of electricity into the energy system. Modern technologies struggle in today's energy markets due to high costs relative to their market value.

Distributed battery storage

Batteries use chemical reactions with two or more electrochemical cells to enable the flow of electrons (e.g. lithium-based[12], NaS, and lead-acid batteries). The battery is charged when excess power is available and later discharged as needed. This storage technology can be used for both short- and long-term applications (i.e. both power and energy services) and benefits from being highly scalable and efficient (Rastler, 2011). Furthermore, it can be installed throughout the energy system and has already achieved limited deployment in both distributed and centralised systems for mobile and stationary applications at varying scales. Widespread deployment, however, is hampered by challenges in energy density, power performance, lifetime, charging capabilities, and costs.

12. Examples of lithium-based batteries include lithium-ion, lithium-polymer, lithium-air, and lithium -ceramic.

Long-term (hours-seasons) storage applications

PSH are currently the most mature and widespread method for long-term electricity storage (IEA, 2012). In addition, two CAES facilities have been successfully used by utilities in the United States and Germany for several decades (Konidena, 2012). These technologies face high upfront investment costs due to typically large project sizes and low projected efficiencies for non-adiabatic CAES design proposals. In the case of pumped hydro and CAES, geographic requirements can lead to higher capital costs.

Today, there are two CAES systems in commercial operation, both of which use natural gas as their primary onsite fuel and are equipped with underground storage caverns. The larger of these two facilities is a 321 MW system in Huntorf, Germany. Commissioned in 1978, this system uses two caverns (300 000 m^3) to provide up to 425 kilograms per second (kg/s) of compressed air (pressure up to 70 bars) produce efficiencies up to 55%. The other system, in McIntosh, Alabama, uses flue gas from its natural gas power plant for preheating to increase overall power plant efficiency (US DOE, 2013).

Hydrogen storage

Hydrogen storage can be used for long-term energy applications. Electricity is converted into hydrogen, stored, and then re-converted into the desired end-use form (e.g. electricity, heat, synthetic natural gas, pure hydrogen or liquid fuel). These storage technologies have significant potential due to their high energy density, quick response times, and potential for use in large-scale energy storage applications. However, these technologies struggle with high upfront costs, low overall efficiencies and safety concerns, as well as a lack of existing infrastructure for large-scale applications (e.g. hydrogen storage for fuel-cell vehicles). This type of electricity storage will be discussed in-depth in the forthcoming IEA Hydrogen Technology Roadmap.

Box 5: Sodium-sulphur battery for transmission infrastructure deferral and voltage regulation in the United States

The city of Presidio, Texas, is located in the deserts of West Texas on the banks of the Rio Grande River. Prior to 2010, the city suffered from a large number of power outages because the only transmission line bringing power from neighbouring Marfa, Texas to Presidio was a 60 mile, 69 kilovolt (kV) line constructed in 1948. This aging transmission line crosses harsh terrain and its deteriorating condition and frequent lighting strikes have resulted in unreliable power for the residents of Presidio.

Electric Transmission Texas proposed the construction of a NaS battery system, a second 138/69kV autotransformer at Marfa's Alamito Creek Substation, and a new 69kV transmission line connecting the Alamito Creek Substation to Presidio. Both the Public Utility Commission of Texas (PUCT) and the Electric Reliability Council of Texas (ERCOT) approved the proposal. The battery was energised in late March 2010 and dedicated on 8 April 2010 (ETT, 2013).

The energy storage system is a 4MW, 32MWh NaS battery consisting of 80 modules, each weighing 3 600 kg. The total cost of the battery system was USD 25 million and included USD 10 million for construction of the building to house the batteries (built by Burns & McDonnell) and the new substation at Alamito Creek. The proposed additional transmission line had an approximate cost of USD 45 million, yielding a total project cost of USD 70 million (Reske, 2010). The battery system is controlled by an energy management system with a controller and power converter that facilitates the battery charging and discharging process in response to real-time conditions of the grid (S&C Electric, 2013).

The Presidio battery system and additional transmission line were financed through ERCOT as a "necessary transmission upgrade" for the residents of Presidio, even though the cost to supply the city with reliable power was high compared to the number of people served and the total amount of power sent to residents. As such, the cost was shared among all transmission and distribution providers and passed on to all rate-paying customers through a common ERCOT-wide "postage-stamp transmission rate" fee. It has been and continues to be ERCOT's policy to use this approach to pay for all transmission upgrades necessary to ensure reliable service to all customers.

The primary purpose of the Presidio NaS battery is to provide backup power for an aging transmission line and to reduce voltage fluctuations and momentary outages for the city and residents of Presidio. The battery system can respond quickly to rapid disturbances as well as supply uninterrupted power for up to eight hours in the case of an extended transmission outage. Between 2001 and 2006 there were 247 power outages, including nine long-term outages with an average duration of 6.8 hours. Additionally, between 8 July and 8 September 2007 there were 81 poor voltage quality events (ERCOT, 2008). The NaS battery was designed to minimise these power disturbances and fluctuations starting from its inception in 2010 until the new 69kV line could be completed in 2012. After completion of the new transmission line, the battery system remains a source of both voltage support and backup power in case fierce storms (that are common in the West Texas region) disrupt Presidio's main electricity supply line.

Thermal storage

Thermal energy storage (TES) technologies operate with a goal of storing energy for later use as heating or cooling capacity. Individual TES technologies operate in the generation and end-use steps of the energy system and can be grouped by storage temperature: low, medium, high. Thermal storage technologies are well suited for an array of applications including seasonal storage on the supply-side and demand management services on the demand-side portion of the energy system (IEA-ETSAP, 2013). As heating and cooling requirements represent 45% of the total energy use in buildings, these demand-side services can represent significant value to the energy system (IEA, 2011).

Some thermal energy storage technologies have already realised significant levels of deployment in electricity and heat networks, including UTES systems and ice storage systems for residential cooling. Further, some end-use technologies that have already been deployed to meet other societal requirements include TES capabilities, though this potential is not currently being fully realised (e.g. residential hot water heaters). Today's R&D in thermal energy storage is primarily focused on reducing the costs of high-density storage, including thermochemical process and phase-change material (PCM) development (European Association for Storage of Energy [EASE]/EERA, 2013).

Thermal energy storage for low-temperature (<10°C) applications

Cold-water storage tanks in commercial and industrial facilities are already installed around the world to supply cooling capacity. Larger UTES systems, including aquifer thermal energy storage (ATES) and borehole thermal energy storage (BTES), have been successfully commercialised in order to provide both heating and cooling capacity in countries such as the Netherlands, Sweden, Germany, and Canada.

Due to the higher energy storage densities seen with PCMs compared to sensible heat storage, the United States and Japan have already installed significant amounts of thermal storage that uses ice for cooling applications. In the United States, an estimated 1 GW of ice storage has been deployed to reduce peak energy consumption in areas with high numbers of cooling-degree days (O'Donnell and Adamson, 2012).

Beyond water, significant R&D activities have been dedicated to developing other PCMs for the transportation of temperature sensitive products. Thermochemical storage – where reversible chemical reactions are used to store cooling capacity in the form of chemical compounds – is currently a focus in thermal storage R&D projects due to its ability to achieve energy storage densities of five to 20 times greater than sensible storage.

Thermal energy storage for medium temperature (10°C-250°C) applications

Distributed thermal energy storage has been around for decades in countries such as New Zealand, Australia and France that use storage capabilities in electric hot water storage heaters. By allowing the heater system to be controlled by the local utility (or distribution company in cases with market liberalisation), the demand from these systems is used to manage local congestion and

Box 6: Increasing system efficiency via waste heat utilisation

Waste heat represents a significant opportunity for improving the efficiency of global energy systems. The potential magnitude of its contribution is difficult to quantify, however, as this value is a function of not only the amount of heat available but also the quality (including temperature and pressure) of this heat. Furthermore, potential uses for waste heat resources are dependent on demand in nearby areas and on the availability of thermal energy networks. These difficulties have prompted new regulatory measures including the recent European Union Energy Efficiency Directive (EU, 2012) that calls for member countries to complete comprehensive assessments of national heating and cooling potentials from resources including waste heat.

R&D efforts focused on improving system maintenance and control systems could provide a key to unlocking these waste heat resources. In addition, thermal energy storage could be used to match heat supply with demand where temporal or geographic gaps exist, in the presence or absence of district heating and cooling infrastructure.

has reduced residential peak demand. In France, for example, thermal storage capabilities in electric water heaters are used to achieve a 5% annual peak reduction (Box 7).

Borehole and aquifer UTES systems have been successfully deployed on a commercial scale to provide heating capacity in the Netherlands, Norway and Canada. These systems utilise holes drilled deep into the ground to store and release energy for heating. Pit storage – where hot water is stored in a covered pit – is used throughout Denmark's district heating networks.

Thermochemical storage systems can be designed to discharge thermal energy at different temperatures, making them an appealing option for medium temperature thermal energy storage applications. As with low-temperature applications, this storage mechanism's relatively high energy density potential has prompted significant R&D efforts.

Thermal energy storage for high-temperature (>250°C) applications

Perhaps the most well-known form of thermal energy storage for high-temperature applications is currently found in molten salts. This material is used to increase the dispatchability of power from CSP facilities by storing several hours of thermal energy for use in electricity generation (IEA, 2010). Heat storage with PCMs, thermochemical energy storage, and waste heat utilisation methods offer many potential opportunities. However, these technologies will need to overcome containment vessel design and material stability challenges at very high temperatures before they can achieve widespread deployment.

Box 7: Peak demand reduction using residential hot water heaters in France

In France, the thermal energy storage capacity in existing electrical water heaters is currently responsible for reducing the nation's winter peak electricity demand by an estimated 5 GW (5%).

Table 7: Electric water heating: residential consumption

2010	*Electricity use for water heating (TWh)*	*Share of residential electricity use (%)*
European Union	93	22
Germany	23	27
France	20	43
Italy	7.4	25
United Kingdom	6.1	9
Spain	5.8	11
Belgium	3.3	29
Czech Republic	2.9	31
Netherlands	2.1	13
Ireland	1.8	34
Austria	1.8	21
Sweden	1.8	20
Finland	1	19
Greece	1.3	38
United States in 2005	123	20

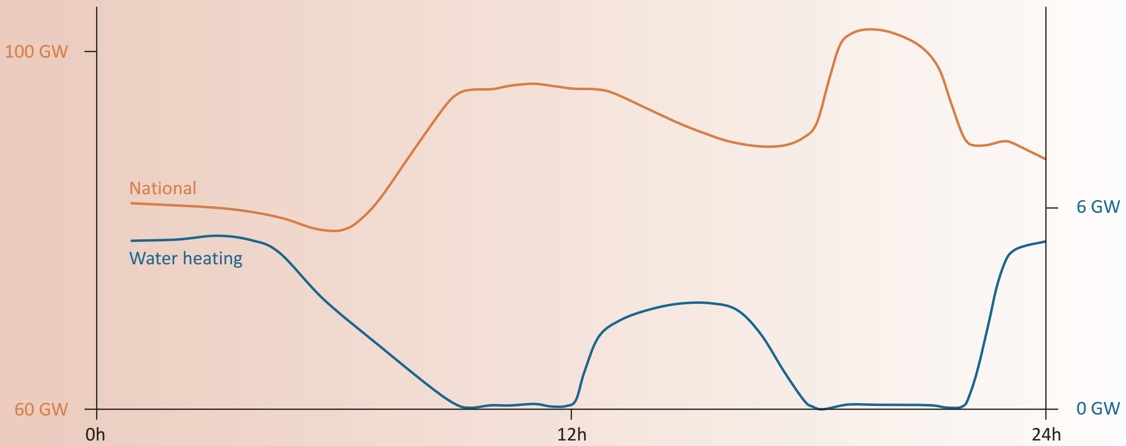
Source: Enerdata (2011), Odyssee, the Europe Energy Efficiency Project, (database), Grenoble, France, http://enerdata.net/enerdatauk/solutions/data-management/odyssee.php and EIA (Energy Information Administration) (2013), Annual Energy Outlook, Washington, D.C.

Box 7: Peak demand reduction using residential hot water heaters in France (continued)

Electrical water heating has been widely used in many countries and is responsible for approximately one-fifth of total residential water heating usage in EU countries and the United States. In France, more than one-third of households use electrical water heaters equipped with a "2-period meter," which allows these water heaters to be used as distributed thermal storage resources (Enerdata, 2011; EIA, 2013).

These meters also allow customers to respond to the country's peak-pricing structures, which were first implemented in the 1960s. In 2013, EDF quoted off-peak electricity prices at EUR 100/MWh versus EUR 130/MWh for peak electricity.

Figure 5: Stylised French load curves (cold weekday in winter)



Source: Hercberg, S. (2013), Personal communication.

This reduction was achieved in part thanks to consumer information campaigns on electricity pricing structures (peak versus off-peak pricing) and a remote start/stop function option that allows grid operators to remotely control these water heaters.

As a result of this peak reduction, French utilities claim that thermal energy storage has helped the country optimise its use of the nation's generation capacity. At the same time, it has helped France reduce its energy-related CO_2 emissions by limiting the use of expensive fossil fuel-fired peak generation plants (Hercberg, 2013).

Vision for deployment to 2050

The vision presented in this roadmap is that of electricity storage in the 2DS of *Energy Technology Perspectives 2014*. Due to data and modelling capability constraints, this vision is limited to the use of four categories of grid-connected electricity storage technologies[13] for supplying daily energy storage needs in China, India, the European Union and the United States, where load-levelling applications help optimise the high penetration of variable renewable generation. Within these constraints, under a scenario where variable renewable electricity reaches between 27% and 44% of electricity production in 2050, an estimated 310 GW of additional storage would be needed in these four major regions, which make up 85% of electricity demand in 2050.

To complement this four-region 2DS vision for energy storage deployment to 2050, three country-specific visions are also included.[14] Researchers in these countries, using scenarios developed to achieve power sector decarbonisation objectives in 2050, supported the development of these cases.

This limited 2DS vision does not imply a lack of large-scale potential for thermal energy storage technologies nor for other electricity storage systems, including those for application in remote communities and off-grid. Rather, it illustrates the need to establish international and national data co-operation to support more comprehensive global energy storage potential assessments, foster energy storage research, monitor progress, and assess R&D bottlenecks. Furthermore, the significant heating and cooling demand in buildings and heating demand in industry in the 2DS illustrate some of the potential applications for thermal energy storage technologies. These demands are shown in the energy storage roadmap insights.

Electricity storage technologies could provide services in a variety of applications across the energy system, from addressing power quality to providing energy arbitrage or seasonal storage. However, assessing the size of the future markets for each application, and the penetration that storage technologies could reach in each, depends fully on the characteristics of specific electricity systems: the competing options available, the penetration and location of variable renewables, and the level of development of electricity grids (IEA, 2014b).

Three variants of the 2DS are developed – the 2DS; a "breakthrough" scenario with aggressive cost reductions for storage technologies; and an "electric vehicle" (EV) scenario with demand response from charging the EV fleet, adding flexibility to the system – where storage technologies compete for these services with future sources of thermal electricity generation and demand response under a variety of assumptions. In the 2DS, daily electricity storage costs are assumed to reach the current cost of pumped hydro storage technologies, while in the breakthrough scenario aggressive cost reductions facilitate increased deployment of storage.

In the section following this constrained vision for daily electricity storage, actions are recommended take a more holistic approach. Specifically, they revert to the broader perspective of both electricity and thermal energy storage technologies across the whole energy system.

The *ETP 2014* scenarios for a clean energy transition

The *ETP 2014* 2DS is taken as the reference scenario in this roadmap. The foremost feature of the 2DS is a core of clean electricity, with renewable energy technologies increasing their share of worldwide electricity generation from about 20% to 65% by 2050, with variable renewables supplying 29% of total electricity production globally.

13. Pumped-storage hydropower (PSH), compressed air energy storage (CAES), flow batteries, and a generalised "other" battery technology.

14. For the United States, Germany and China.

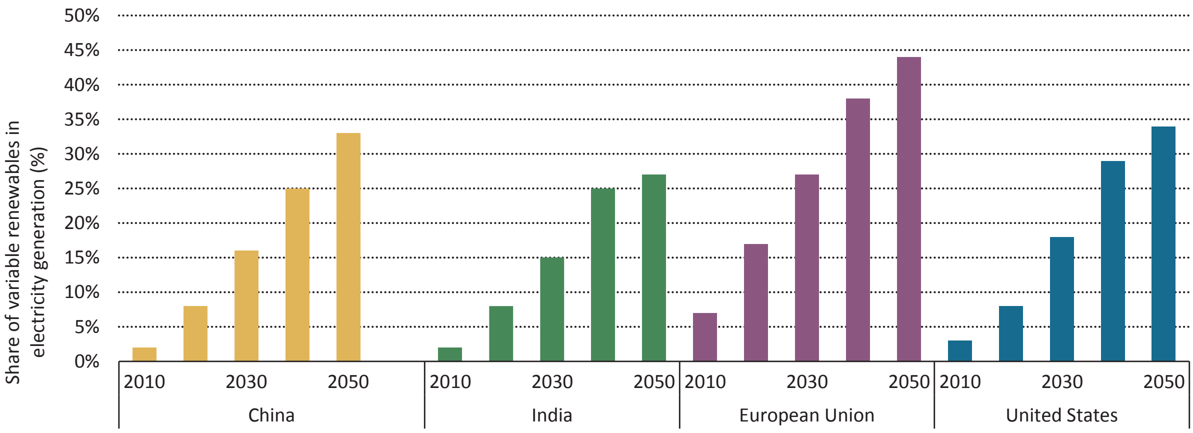
Box 8. *Energy Technology Perspectives (ETP)* 2DS

The IEA *ETP* 2DS describes how technologies across all energy sectors may be transformed by 2050 to give an 80% chance of limiting average global temperature increase to 2°C. It sets the target of cutting energy-related CO_2 emissions by more than half by 2050 (compared with 2009) and ensuring that they continue to fall thereafter. The 2DS acknowledges that transforming the energy sector is vital but not the sole solution: the goal can only be achieved if CO_2 and GHG emissions in non-energy sectors are also reduced. The 2DS is broadly consistent with the *World Energy Outlook* 450 Scenario through to 2035.

The model used for this analysis is a bottom-up TIMES (The Integrated MARKAL-EFOM System) model that uses cost optimisation to identify least-cost mixes of technologies and fuels to meet energy demand, given constraints such as the availability of natural resources. The *ETP* global 28-region model permits the analysis of fuel and technology choices throughout the energy system, including about 500 individual technologies. The model, which has been used in many analyses of the global energy sector, is supplemented by detailed demand-side models for all major end uses in the industry, buildings and transport sectors.

Large regional variations exist – reflecting differences in renewable resource availability and alternatives for decarbonisation elsewhere in the energy system – with respect to the level of variable renewable electricity generation, which ranges from 20% to 55% worldwide. Storage will compete with other options to provide the flexibility needed to accommodate these resources, which sets the context for the vision for storage technologies in this roadmap.

Figure 6: Share of electricity generated from variable renewables (%) by region in the 2DS



The *ETP 2014* publication explores the future role of daily electricity storage technologies under a range of sensitivities regarding future costs and performance of storage and competing technologies, including flexible thermal power generation and to some extent, demand response (IEA, 2014b). Three of these variants are reproduced in this roadmap:

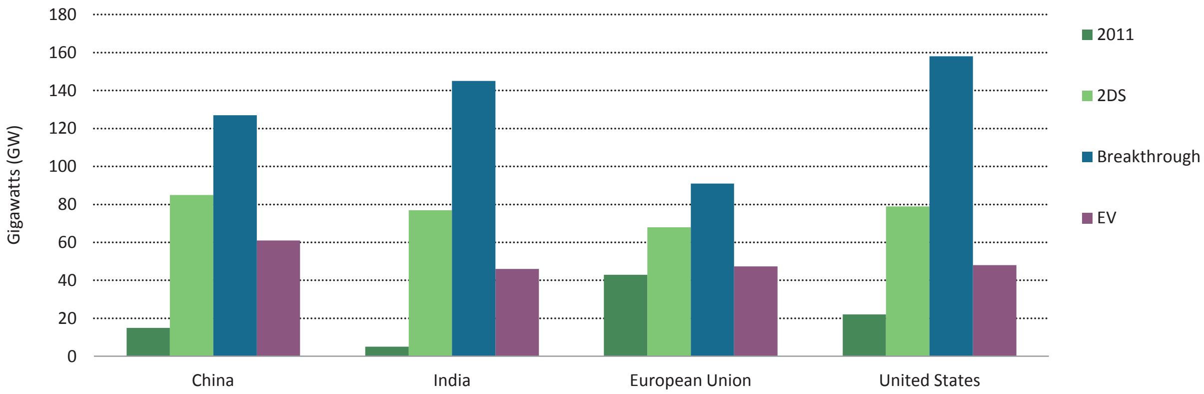
- the 2°C Scenario (2DS)
- a "breakthrough" scenario, with aggressive cost reductions in storage technologies
- an "EV" scenario, where demand response from "smart" charging of the electric vehicle fleet in the 2DS provides additional flexibility to the system.

Three scenarios for electricity storage deployment

The *ETP* 2DS scenario serves as a reference case, determining the capacity expansion of power generation technologies from now to 2050 to meet low-carbon objectives. The flexibility of the resulting system is then explored using a linear dispatch model where the cost of operating the electricity system is minimised by determining the dispatch of generation and storage technologies during every hour in a given year. This approach permits a detailed assessment of the storage needs within the power generation fleet from the 2DS under a range of conditions with other technologies competing to provide the same services. Full detail on the modelling and scenario assumptions can be found in Annex B.

The 2DS assumes the cost of technologies providing daily storage for arbitrage applications in 2050 will be that of the lowest-cost technology providing this service today: PSH. In the 'breakthrough' scenario, aggressive reductions in specific energy (per MWh) and power capacity (per MW) storage costs facilitate an increased deployment of storage. Finally, in the electric vehicle scenario, charging strategies for offsetting peak demand are widely employed and the need for additional large-scale storage in the six- to eight-hour duration range is reduced. The resulting electricity storage capacities in 2050 are summarised in Figure 7.

Figure 7: Electricity storage capacity for daily electricity storage by region in 2011 and 2050 for *ETP 2014* scenarios



Cost targets in a "breakthrough" scenario

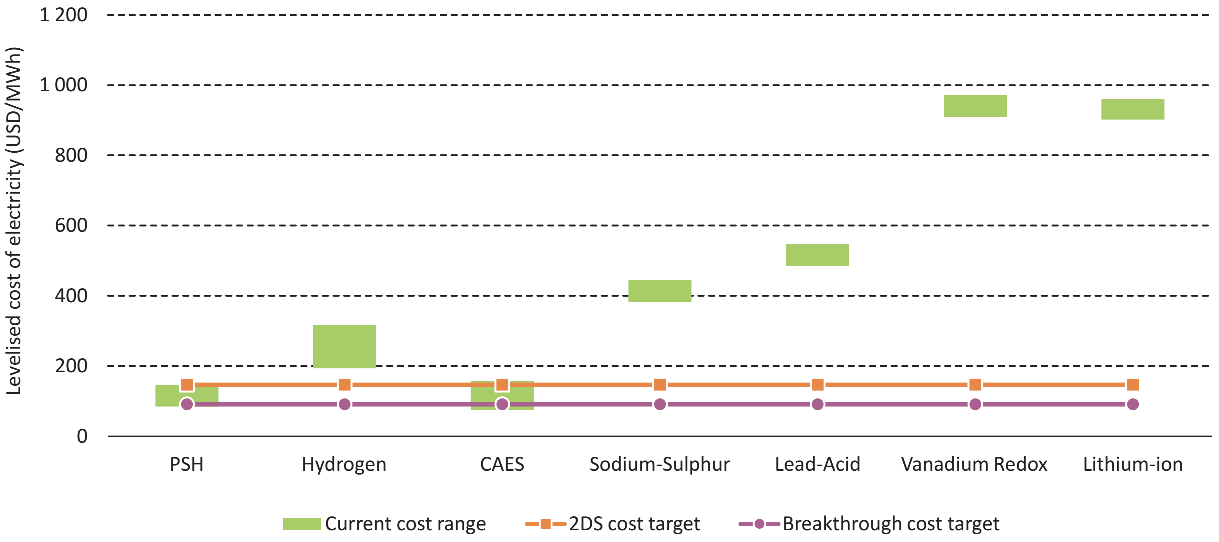
The "breakthrough" scenario is designed as an estimation of the highest penetration of daily electricity storage in the 2DS scenario. This scenario assumes aggressive cost reductions in electricity storage technologies for arbitrage applications, where these technologies become competitive with the least expensive option currently providing arbitrage services.[15] This result translates to a levellised cost of energy (LCOE) for daily bulk storage of approximately USD 90/MWh (Figure 8). The LCOE includes the cost of the initial technology infrastructure investment, operation and maintenance, and electricity used to charge the storage facilities.

At this LCOE, electricity storage technologies provide all the flexibility requirements in all regions in the 2DS. These cost reductions, however, are highly ambitious – for PSH and CAES, significant reductions in civil engineering costs have already reduced the overall cost of PSH. As these costs account for nearly half of the initial capital investment, improvements in the turbine technology itself would have a relatively low overall impact. However, because of the high initial capital investments required for these facilities, potential

15. Currently a combined cycle gas turbine operating at load factors of 30% to 60%.

cost reductions could be found in lowering the cost of capital for new large-scale storage projects. For battery technologies, these cost reductions could be very aggressive, considering their energy specific costs (per kWh) would need to come down by a factor greater than ten.

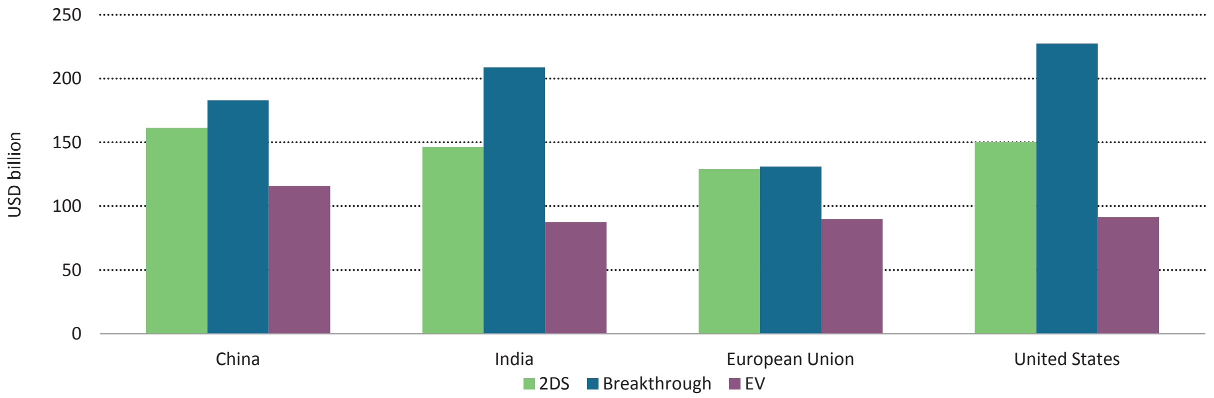
Figure 8: LCOE in the "breakthrough" scenario in 2013 and 2050



Competition with demand-side response

A large-scale rollout of demand response technologies could compete against electricity storage in many applications. The 2DS anticipates a large rollout of EVs. The "EV" scenario assumes that 25% of the daily electricity requirement from EVs is controllable load, available for demand response services. Again, this represents an extreme case: while the energy storage potential in EVs might be used for grid optimisation, home-to-vehicle or vehicle-to-home applications might be more prevalent than vehicle-to-grid.

Figure 9: Investment needs for energy storage in different scenarios, 2010 to 2050



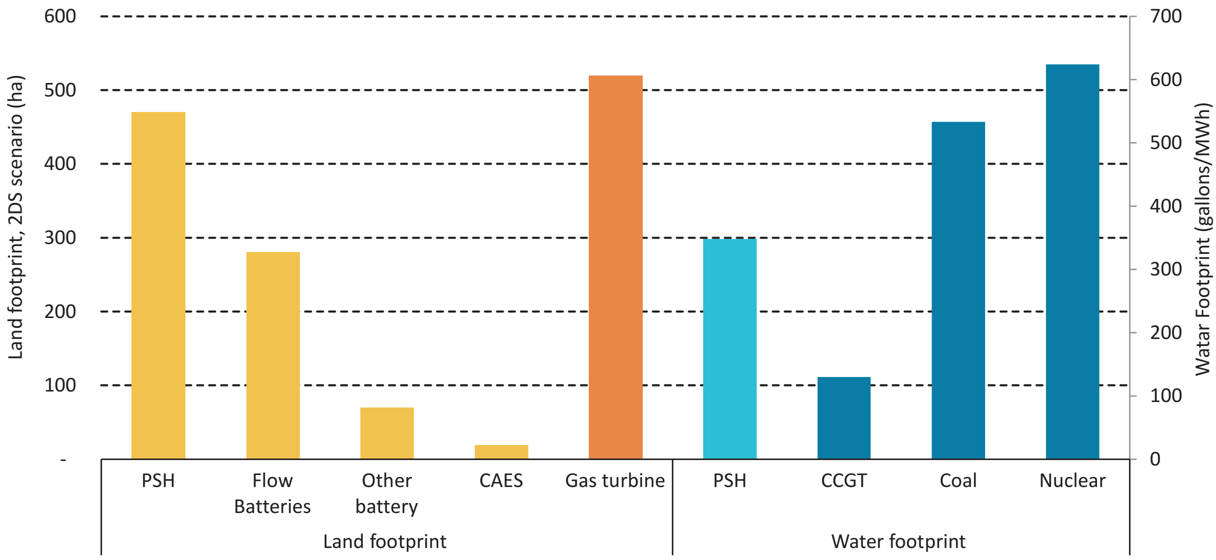
Investment needs for storage

The level of investment required in electricity storage technologies varies the different scenarios, from an estimated USD 380 billion in the four regions modelled in the EV scenario to USD 590 billion in the 2DS and USD 750 billion in the breakthrough scenario. Capital costs for electricity storage technologies are assumed to be USD 1 500/kW and USD 50/kWh in the 2DS and EV scenario, while in the breakthrough scenario they are assumed to be 1 200/KW and USD 30/kWh in 2050. These investment needs are just a fraction of the USD 18 trillion investments needed in power generation in the 2DS in these four regions.

Environmental impacts of storage in the *ETP* 2DS

The large-scale deployment of electricity storage and power generation technologies across all the cases studied engenders some environmental impacts that should not be overlooked. In Figure 10, a comparison with conventional energy technologies shows a similar impact. Aggregate figures are of limited value, however, since ultimately it is individual projects that have a high impact locally and could face significant barriers for deployment. These issues will be discussed further in the policy and regulation sections below.

Figure 10: Land and water footprint for electricity storage and generation technologies



Source: Decourt, B. and R. Debarre (2013), "Electricity storage", *Factbook*, Schlumberger Business Consulting Energy Institute, Paris, France. National Energy Technology Laboratory (NETL) (2010), "Life cycle analysis: supercritical pulverized coal (SCPC) power plant, NETL, September, Pittsburgh. National Renewable Energy Laboratories (NREL) (2013), *Renewable Electricity Futures Study (RE Futures)* Golden, CO, United States, www.nrel.gov/analysis/re_futures/.

Regional factors for energy storage deployment

The array of possible services that storage technologies can provide makes it difficult to define detailed global development and deployment scenarios. Furthermore, the operational feasibility of benefits-stacking by a particular system is subject to local regulations and market structures. Since the costs and benefits of energy storage are region-specific, optimum scenarios need to be developed on smaller scales, with particular focus on regional needs and future generation mixes.

Countries and regions adopt energy storage technologies in context with their economic, environmental, and energy goals. Therefore, wherever possible, the costs and benefits of specific technologies or technology classes should be assessed in this context. The following regional characteristics should be taken into account when analysing potential deployment opportunities:

- current and future energy supply mix and demand profiles, including resource availability
- regulatory and market structure, including pricing structure for energy and power services
- status of existing and planned infrastructure investments, including those for transmission and distribution grids
- current level of and future needs for system flexibility
- other competing options for system flexibility.

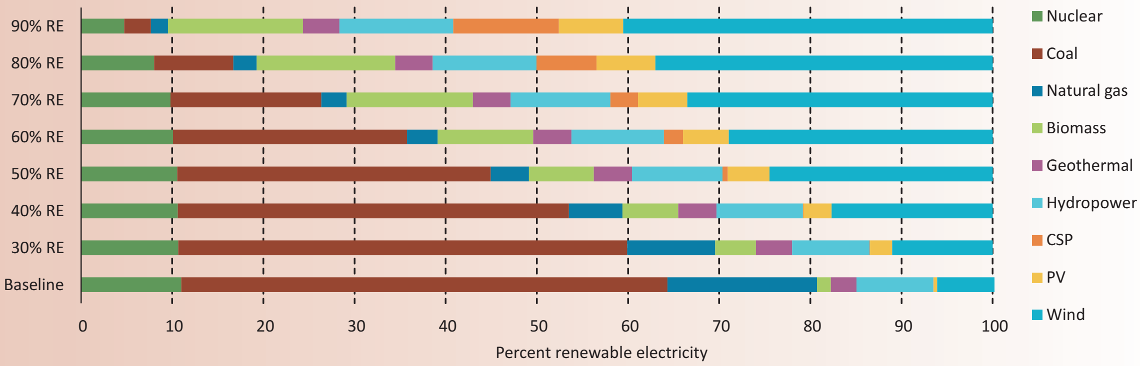
Box 9: A vision for electricity storage in a high renewable electricity future in the United States

In the United States, significant energy storage potential exists for both electricity and thermal storage technologies. Today, there are over 2GW of installed thermal storage capacity in the country, not including the storage capabilities found in existing infrastructure (e.g. residential hot water heaters and commercial refrigeration systems can provide demand shifting capabilities to the energy system) (Ecofys and Bonneville Power Administration, 2012). There is also an estimated 23 GW of electricity storage capacity connected to the nation's electricity grid, the vast majority of which is provided by existing pumped hydro systems along with limited amounts of CAES (one system in Alabama), batteries, flywheels, and other storage technologies.

In 2012, the United States Department of Energy published a comprehensive study that evaluated the potential for a national transition to a predominately (up to 80%) renewable electricity supply. The broad goal of this analysis was to determine the maximum proportion of renewable electricity generation that could be incorporated into the Unied States electricity grid using currently available technologies. Explicitly included in the resulting "Renewable Electricity Futures Study" report were three electricity storage technologies – PSH, CAES, and a generalised battery storage system. Furthermore, thermal storage for CSP systems was included to provide system flexibility.*

* In this study, all CSP facilities included six hours of thermal storage.

Figure 11: Generation mix in 2050 in the United States for a range of scenarios (low-demand)



Source: Modified from National Renewable Energy Laboratories (2013), "Renewable Electricity Futures Study" Colorado.

(.../...)

Box 9: A vision for electricity storage in a high renewables future in the United States (continued)

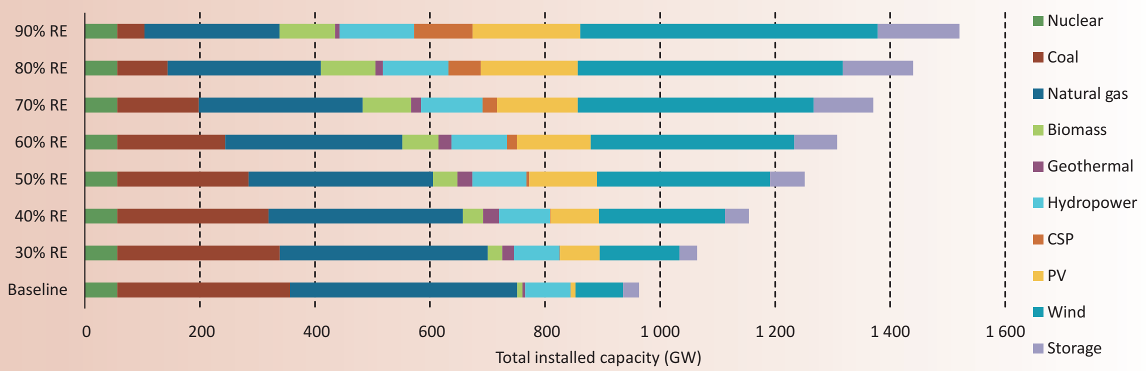
Using cost inputs from an independent and external consultancy group, Black and Veatch, this study concluded that currently available renewable electricity technologies could reliably supply 80% of total electricity generation in the United States by 2050, in combination with a more flexible electric system. At this 80% renewables level, almost 50% of total generation in this United States study came from variable renewable resources.

In this future scenario, system flexibility is provided using a portfolio of supply- and demand-side options including flexible generation, grid storage, new transmission lines, a more responsive demand side, and operational changes (e.g. evolved business models and new market rules). Datasets were used with hourly resolution, and resource adequacy had to be met on this basis over a calendar year. Operational considerations below the one-hour timescale were not comprehensively incorporated.

The baseline scenario in the 2012 “Renewable Electricity Futures Study” projects that the nation’s total installed electricity storage capacity would grow to between 103 GW and 152 GW in 2050, exclusive of the thermal energy storage deployed in conjunction with new CSP facilities. This capacity growth is primarily achieved through the addition of several new CAES facilities. This range is mostly due to assumptions related to transmission grid expansion, where the study observed decreasing total storage capacity with increasing new transmission investments.

It must be noted that this study did not take into account FERC Orders 755 or 784, which were released after the RE Futures analysis was complete and would have likely impacted the cost-benefit analysis for energy storage technologies. Considering the lack of analysis below the one-hour time resolution and the fact that only three large-scale options for energy storage were considered in this study, the total market potential for energy storage in the electricity grid is likely larger than the amount deployed in this analysis. Conversely, new challenges with respect to the technical feasibility of using saline aquifers for new CAES systems have come to light since this study.

Figure 12: Installed capacity in 2050 as renewable electricity levels increase (low-demand scenario)



Source: National Renewable Energy Laboratories (NREL) (2013), *Renewable Electricity Futures Study (RE Futures)* Golden, CO, United States, www.nrel.gov/analysis/re_futures/.

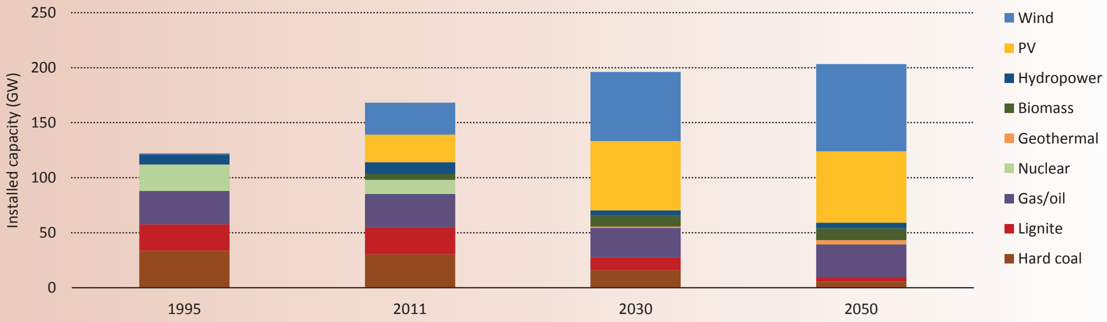
Note: this section was prepared with support from the U.S. Department of Energy.

Box 10: Energy storage to support energy efficiency and renewables in Germany

In September 2010, the German government announced its new national energy transition concept ("Energiewende"). Under this concept, Germany will strive to reduce primary energy demand by 50% in 2050 (compared to 2008 consumption levels) while simultaneously decreasing its reliance on fossil fuels. At the same time, the share of renewable energy in the energy supply will increase to 60% in 2050, with renewable electricity contributing 80% of total electricity production. In order to fulfil these goals, the German energy system will need to undergo a widespread transformation.

Significant changes to the German electricity system have been underway since 1995. The installed capacity of renewable technologies has risen from 10.2 GW (23.8 TWh) or 8% of total capacity (mostly hydro) in 1995 to over 70 GW (119 TWh) or 40% of total capacity in 2011. This compares to a maximum peak load of 90 GW in the German grid. Moving forward, a further increase of wind and PV is expected, while nuclear power plants (2011 installed capacity of 12.7 GW) are expected to be phased out by 2022 (BMWI, 2013).

Figure 13: Installed capacity and electricity generation in Germany: 1995, 2011, 2030, and 2050



Source*:* Eurelectric (2009), "Statistics and prospects for the European electricity sector (1980-2000, 2004, 2005, 2006, 2010-30)", *EURPROG 2008,* Eurelectric, Brussels, Belgium and *BMWI (2013) and* BMU (Federal Ministry for the Environement, Nature Conservation and Nuclear Safety) (2012), "Langfristszenarien und trategien fur den Ausbau der erneuerbaren Energien in Deutschland bei Berucksichtigung der Entwicklung in Europa und global", BMU, Berlin.

Currently, thermal energy storage already contributes to improved energy efficiency. In buildings, thermal energy storage can level out night and day temperature differences, reducing energy demand for heating and air conditioning. Used as seasonal storage, these systems can store heat from summer for use in winter. Industrial waste heat can also be utilised by these storage systems. About 12% of the industrial final energy demand in Germany (720 terawatt hours [TWh] in 2010) is available as waste heat at temperatures above 140 °C. The utilisation of this resource represents a potential of 86 TWh in equivalent heat.

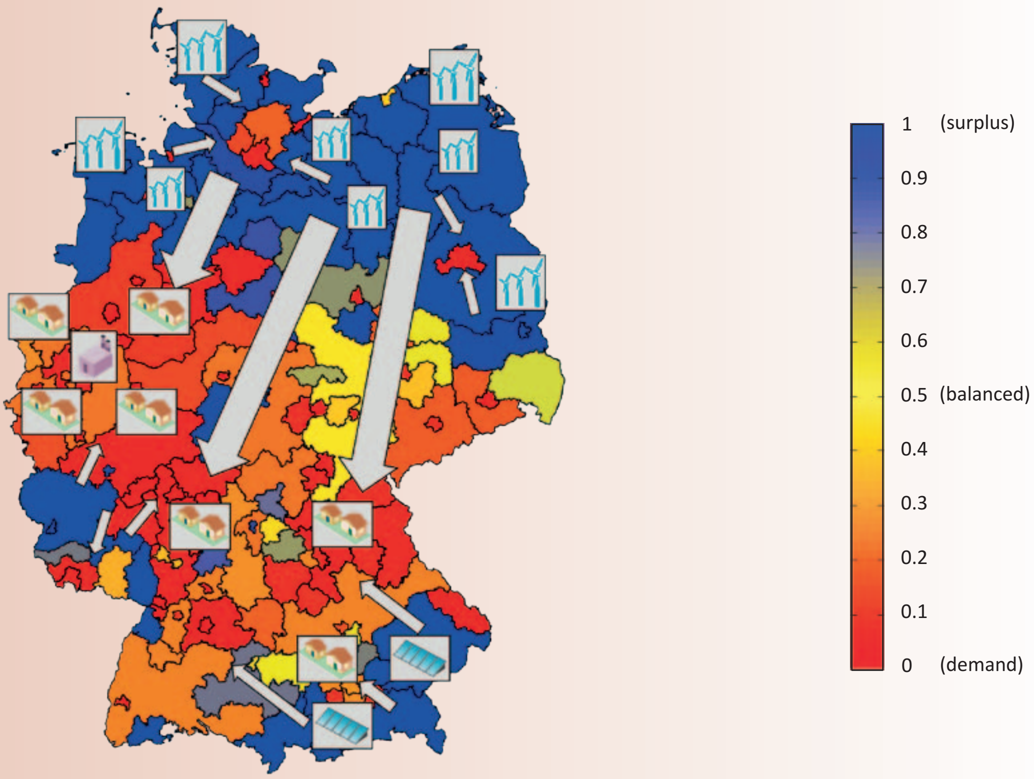
While the imbalances in the electric grid in the 1990s were addressed by using approximately 5 GW (32 GWh) of PSH, current capacity levels have only increased slightly to 6 GW (40 GWh). Today, many factors including geographic mismatch of power supply and demand have led to significant balancing issues from the northern suppliers and southern demand centres. This problem is exacerbated by local grid imbalances resulting from a sharp increase in the supply of wind energy in the north of Germany and a lack of energy supply in the south due to inadequate capacity on transmission lines. The improved integration of the European grid allowing for electricity

(.../...)

Box 10: Energy storage to support energy efficiency and renewables in Germany (continued)

imports and exports has enabled Germany to overcome these balancing issues. However, current saturation of interconnectors, combined with Europe's ambitious plans to increase renewable generation and the potential decreases in interconnection capacity with neighbouring countries, necessitates a more sustainable solution to maintain balance in both the transmission and distribution portions of the electricity grid (THEMA, 2013).

Figure 14: Challenges faced by the electricity sector in Germany



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Note: figure based on results of research project ‚Bedarfsanalyse Energiespeicher' realized by Fraunhofer UMSICHT, supported by the German Federal Ministry of Economics and Technology.

Source: Beier, P. and P. Bretschneider (2013), "Modellbasierte, regional aufgelöste Analyse des Bedarfs an netzgekoppelten elektrischen Energiespeichern zum Ausgleich fluktuierender Energien", final report, Bedarfsanalyse Energiespeicher, Frauenhofer Institute, Munich, Germany, http://www.iosb.fraunhofer.de/servlet/is/37913/04_IOSB_Jahresbericht-2012-2013_Standorte2.pdf.

Moving forward, the main challenge facing the German electric power system will be the local and temporal balancing of electricity supply and demand. While spatial imbalances can be managed or diminished by grid expansion (although this solution faces significant NIMBY [not-in-my-back yard] concerns), trans-regional temporal imbalances must be solved by other means. For short periods and alternating imbalances (excess and lack of energy are alternating problems), electricity storage technologies, demand-side management and virtual power plants* could be adequate solutions. For longer periods or to create a permanent surplus of energy over the year for system reliability purposes, only energy conversion to gas (e.g. power-to-gas) or heat

(.../...)

* A "virtual power plant" refers to a group of distributed energy resources (e.g. small-scale hydropower or CHP facilities).

Box 10: Energy storage to support energy efficiency and renewables in Germany (continued)

(e.g. district heating with additional electric heater or heat pumps) will be sufficient. These solutions require cross-sectoral approaches as they connect the electric grid to heat, cold or gas demand.

Because of the complexity of the problems in Germany (e.g. heterogeneous allocation of feed-in renewables; high and increasing shares of renewable supplies), multiple solutions and various technologies will have to be applied (Table 8).

The creation of a dispatchable load by distributed storage devices – both on the low or medium voltage grid level – will gain importance in the future. Since about 60% of the final energy demand in Germany is for heating and cooling, thermal energy storage technologies are able to provide such a solution. In this context, electricity might be converted into thermal energy ("power-to-heat") to be used right away or stored as cold or heat for later use. This approach could also be applied in the buildings sector and in industry.

Table 8: Options for various energy system applications in Germany

Service provided	Current options	Future storage options
Temporal imbalances (hours to days)	• Curtailment of variable renewables • Electricity storage • Gas turbines • Other fossil power plants • Centralised CHP • Thermal storage	• Batteries (lithium-ion and lead-acid batteries) in households with roof-mounted PV systems • Thermal and electricity storage in decentralised CHP • Thermal storage • Fuel cells • Electricity storage
Regional imbalances	• Electricity exports in Northern Germany to Netherlands and Poland • Imports in Southern Germany from France and Czech Republic • Transmission grid enhancement	• Large-scale batteries (MW scale) at the distribution grid • CAES systems (10s to 100s MW scale) linked to transmission grid • Thermal storage
Long-term storage needs (weeks to months)	• Thermal storage	• Hydrogen storage • Thermal storage • Power-to-gas

Due to power generation and electricity storage technologies, and the fact that all technologies compete with each other, the "electric-energy-storage mix" is not really predictable (Zucker et al, 2013). Limited and rough estimates on the future energy balancing needs vary from 15 gigawatt electrical capacity (GW_{el}) to 30 GW_{el}, in 2030 and from 30 GW_{el} and 45 GW_{el} in 2050 (Droste-Franke, 2013). These figures have to be viewed with caution as they are often based on different underlying assumptions and do not include alternatives such as renewable energy supply curtailment and the use of fossil fuel plants for system balancing.** Furthermore, future cost estimates are unreliable. A rough order of magnitude estimation based on an assumed average cost of roughly EUR 500 kilowatt electrical capacity (kW_{el}) to EUR 2 000/kW_{el} would imply total cumulative investment needs of between EUR 7.5 billion and EUR 60 billion (cumulative costs) in 2030, and between EUR 15 billion and EUR 90 billion in 2050. Additional analysis and information is needed to provide more reliable figures for both energy storage demand potentials and investment costs.

** The definitions of energy balancing demand and energy storage demand are often not clarified, and the differences between positive (discharging) and negative (charging) energy balancing demand and between power and capacity, are often not taken into account.

Note: this section was prepared by members of the IEA Energy Conservation through Energy Storage (ECES) Implementing Agreement.

Box 11: Energy storage to support variable renewable energy resources in China

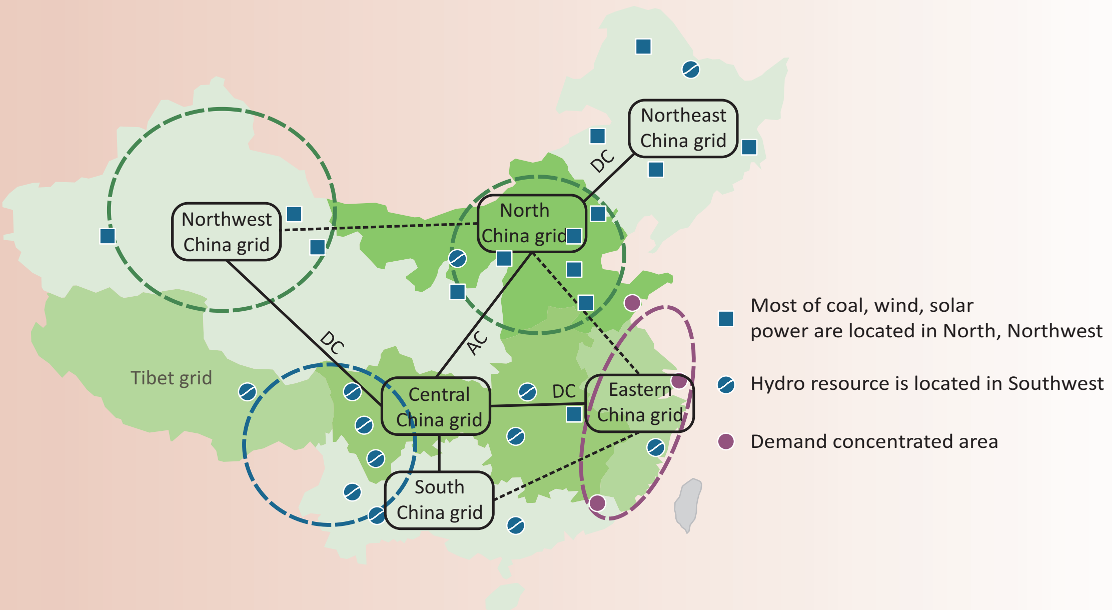
As the world's largest energy producer and consumer, China considers renewable energy resources to be important tools in facilitating an energy transition that will ensure energy security, protect the environment and reduce greenhouse gas emissions. China is experiencing rapid growth in renewable energy generation, and China State Grid's Energy Research Institute (SGERI) is in the process of developing various scenarios for renewable energy deployment for 2050. In these studies, wind and solar capacity are predicted to both reach 1 000 GW under SGERI's 50% renewable grid scenario or respectively 1 500 GW and 1 300 GW under the 70% scenario. (SGERI, forthcoming)

In China, the nation's best renewable energy resources are widely dispersed. Hydropower resources are primarily concentrated in China's Southwest, while wind power is distributed throughout the whole North of the country, as well as the east and southeast coastal areas. China's best solar energy resources are mostly found in the Tibetan Plateau, Gansu, northern Ningxia, southern Xinjiang, and the western parts of Inner Mongolia. While the nation's large-scale renewable energy resources are suitable for utility-scale generation, in general the areas with the most resource potential are remote from demand centres. As a result, long distance transmission UHV (Ultra High Voltage) transmission lines to bring the electricity to demand centers in eastern and central China.

Furthermore, high levels of renewable energy in the Chinese power grids will bring significant challenges in the operation safety and reliability of the power system given the variability of these resources. In addition to traditional coal-fired and gas-fired power plants involved in regulating the power system, energy storage technologies are expected to play an important role in improving system flexibility and supporting the accommodation of renewable energy resources. Under SGERI's high renewable energy scenario studies, it is expected that China's demand for energy storage could reach over 200 GW by 2050.

(.../...)

Figure 15: Future electricity grid configuration in China



This map is for illustrative purposes and is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: Modified from IEA and Energy Research Institute (2011), Technology Roadmap: China Wind Energy Development Roadmap 2050, OECD/IEA, Paris, France.

Box 11: Energy storage to support variable renewable energy resources in China (continued)

By the end of 2012, the accumulated energy storage capacity in China was about 18 GW, of which 57.4 MW was not pumped storage hydropower (PSH). In 2010 and 2011, the construction of demonstration projects achieved great progress with cumulative growth rates at 61% and 78%, respectively. Today, there are nearly 50 storage demonstration projects in the planning and operation stages in China. In these projects, major project applications include the support of wind power (53% of projects), distributed micro-grid projects (20%), and transmission and distribution grid support projects represents (7%).

PSH plants are currently considered the most mature and suitable energy storage technology for large-scale application in China's power system. Generally, it is expected that PSH will maintain a dominant and important role in China's energy storage markets as a support tool for an increasing proportion of renewable energy, ensuring the efficiency of conventional energy and promoting the safety and economy of power system. State Grid's latest analysis expects that total PSH installed capacity will reach 54 GW in 2020 and 100 GW by 2030. As the number of high quality sites decreases for new PSH projects, development is expected to grow more slowly after 2030, to between 110 and 130 GW by 2050 (SGERI, 2014).

Electrochemical energy storage technologies have already been installed in Chinese wind farms for use in smoothing wind turbine output. In the Zhangbei wind, solar, storage and transmission demonstration project a 14 MW lithium iron phosphate battery system has been fully constructed. When the project is fully completed, it will have 500 MW wind, 100 MW photovoltaic and 110 MW of energy storage. In the long run, given resource limitations and economic constraints, China is expected to introduce other mature energy storage technologies into the energy system to meet increasing flexibility needs. It is expected that electrochemical storage technology performance could achieve significant breakthroughs by 2020, resulting in decreased investment costs. With decreasing costs, large storage batteries can be integrated into the power grid for peak load management and frequency regulation applications.

Furthermore, user-side heat, cold and electricity storage could be considered a major tool for improving the energy storage capacity of the power system. Recent analysis by SGERI and the National Development and Reform Commission (NDRC) project that electric vehicles will become popular in China by 2050, potentially leading to a charging shock to the power grids that will need to be managed by policies or technical solutions (e.g. vehicle-to-grid management systems). Large-scale distributed energy storage devices installed on the demand side could also act as "virtual power plants" for meeting peak load. China's expected solar thermal power plant development also introduces opportunities for molten salt thermal storage systems to play a significant role in the energy system.

Overall, in the short and medium term, it is more likely that new PSH plants and natural gas stations will be used to improve the flexibility of power system. If electrochemical energy storage technologies quickly mature, they could be used widely for large-scale applications to effectively support increasing amounts of renewable energy resources in the power system.

Note: this section was prepared by the State Grid Energy Research Institute.

Energy storage technology development: actions and milestones

Energy storage technologies can have a valuable role to play in any energy system, including those with high and low proportions of variable renewable generation. In consultation with expert stakeholders, a series of actions and co-ordinating timelines were developed that will facilitate the accelerated deployment of these technologies in the energy system. This roadmap recommends a set of actions that broadly apply across energy storage technologies as well as a number of technology-specific recommendations. The latter are focused on technologies that appear to be particularly well suited for future widespread deployment. Specific cost targets are not overly emphasised in these actions due to the high sensitivity to regulatory conditions and market design, as discussed later in this roadmap.

Actions spanning across technologies and applications

This roadmap recommends the following actions:		***Proposed timeline***
Address data challenges for existing storage projects.	Create an accessible global dataset of energy storage technology project overviews, including information on system specifications, cost and performance with contextual details.	Concentrated effort in the short term (2014-17).
	Quantify waste heat availability and opportunities, including details on waste heat quantity, quality, and location for both resources and potential demand.	Concentrated effort in the short term (2014-17).
Address data challenges for use in assessing future energy storage potential.	Build a comprehensive dataset of renewable generation production with high levels of granularity to allow for assessment across a wide range of energy storage technology applications throughout the year.	Concentrated effort in the short term (2014-20).
	Assess global potential for energy storage deployment in the context of the ETP 2DS vision (technology-independent evaluation).	Longer-term effort (2020-30) after compilation of necessary datasets.
	Quantify distributed energy storage potential in buildings, e.g. domestic hot water heaters, commercial refrigeration centres.	Concentrated effort in the short term (2014-20).
Establish international and national data co-operation to foster energy storage research, monitor progress and assess the R&D bottlenecks.		2018
Support research, development and demonstration (RD&D) projects that incorporate the use of both electricity and thermal energy storage (i.e. hybrid systems) to maximise resource use efficiency, with emphasis on optimising the location/application factor.		Medium-term effort (2020-50).
Support R&D efforts focused on 1) technology breakthroughs in high-temperature thermal storage systems and for scalable battery technologies and 2) storage systems that optimise the performance of the energy system and facilitate the integration of renewable energy resources.		Concentrated effort from 2014 to 2035.
Identify specific applications and combination of applications that are particularly suited for thermochemical storage system (i.e. high cycles per year).		Medium-term effort (2020-35)

Address data challenges for existing storage projects

Energy storage technologies can be valuable assets throughout the energy system, but quantifying the potential for energy storage is challenging due to current global dataset limitations. Currently accessible global datasets do not include an exhaustive list of projects or project details sufficient to establish an accurate baseline. For the storage projects that are present in existing lists, the following information is not consistently included:

- power (MW) and storage capacity (total MWh charge/discharge)
- information on relevant government and policy landscapes, funding schemes, realised fixed and variable costs, execution details, and operating constraints
- details regarding quantity, quality, and location of both the supply resources and corresponding demand for waste heat.[18]

To encourage the accelerated deployment of electricity and thermal energy storage technologies, governments should support the development of an accessible global database of existing electricity and thermal storage projects that includes the above details. This effort could partner with existing efforts.[19] Once this dataset is established, it should be routinely updated as new data become available.

Assess global energy storage technology potential

Once a baseline is effectively established, global energy storage technology potential assessments can be completed beyond a technical-potential level. However, further difficulties hinder attempts at quantifying energy storage potential by application. Primary challenges include a lack of easily accessible renewable energy production, heating and cooling demand curves, and waste heat availability datasets with sufficient levels of granularity (sub-hourly level) reflecting observed system behaviour across long time frames. Access to these types of datasets will allow for the detailed modelling and quantification of the total energy storage potential (technology-independent) across the energy system.

While these more granular datasets are being built and compiled, global technical potential assessments should be completed. For capital-intensive storage projects including PSH, CAES, and UTES technical constraints and geographical requirements should be evaluated. Of particular interest here is new information related to CAES technologies, which indicates that previous siting evaluations may have drastically overestimated the number of naturally existing caverns suitable for this application (Denholm, 2013).

Separate efforts should be made to quantify the current distributed energy storage potential in existing infrastructure. Commercial refrigeration facilities and domestic hot water heaters in particular represent significant thermal energy storage potential. According to research to date, the former could be an appealing option for storing excess energy from renewable energy resources. The latter could be a valuable load-shedding resource as is already seen in France, where residential electric water heaters are responsible for an almost 5 GW peak reduction in the winter months. This reduction is made possible through a combination of peak-pricing tariffs, a remote start/stop system for electric water heaters, and significant consumer awareness campaigns (Box 7). In Japan and China, ice and cold-water storage systems are already reducing peak energy demand from buildings.

In quantifying these potentials, attention should be paid to other technologies that can supply the same energy or power services. For example, larger planning areas, flexible thermal generation, and new transmission and distribution infrastructure can be used for many of the same applications. Further, as energy storage technologies will not operate with 100% efficiency, these losses should be included in any calculations.

International and national data co-operation can foster electricity storage research, monitor progress and assess the R&D bottlenecks. Major discrepancies in current and future storage technology costs show the significant uncertainty around future storage R&D progress, and rapid technology development shows the need for industry involvement.

18. In some regions, domestic electric water heaters are well deployed and used as thermal storage for load leveling purposes, but total capacity and potential are not captured in global datasets.

19. For example, the US Department of Energy's Global Energy Storage Database.

Short-term (seconds-minutes) storage applications for reserve services and frequency regulation

This roadmap recommends the following actions:	*Proposed timeline*
Reduce the energy cost of flywheel technologies through increasing overall efficiency, in particular through reducing frictional losses in the system.	2014-30
Improve the performance of and manufacturing techniques for supercapacitors through testing and demonstration.	2014-30
Improve cooling technologies for SMES systems.	2014-30 Ongoing to 2050

For shorter-duration reserve services and frequency regulations, flywheels, supercapacitors, and SMES systems could provide significant value in the electricity system. However, flywheel technologies currently struggle from low energy densities and the resulting high cost for use in applications in the electricity system. Today's designs suffer, in particular, from frictional losses (e.g. windage and bearing). Their modularity and distributed nature makes them suitable for some applications, however, so emphasis should be placed on reducing these losses.

Current SMES systems and supercapacitor technologies can be generally categorised as having high cycle lives and power densities, but much lower energy densities than other electricity storage options. Both face the obstacle of large cooling requirements, which reduces overall efficiency. The high cycle lives and power densities make these technologies prime candidates for valuable power application needs, including frequency regulation. Given this significant potential role, future research should focus on reducing system-cooling costs, increasing system energy density, and proving performance through documented demonstration projects.

Distributed battery storage for renewables integration, frequency regulation

This roadmap recommends the following actions:	*Proposed timeline*
Improve battery assembly design to improve system reliability and performance.	2014-30
Demonstrate system performance and safety through targeted demonstration projects in the context of multiple applications and share results with stakeholder community.	2014-24
Support material research and efficiency gains via mass production for battery systems to improve energy density and reduce costs for sodium-sulphur, lithium-based, redox flow, and other advanced batteries. Overall target of USD 1 000/kW for new on-grid battery systems.	2014-35
Support materials research to mitigate safety and environmental risks of battery systems in stationary and mobile applications.	2014-30
Improve the operation management of battery systems, both centralised and distributed.	2014-20

The scalability of battery storage systems makes them well suited to a large array of applications and locations in the energy system. Today, batteries are cost competitive or near-competitive for many off-grid and remote community applications. However, today's battery systems struggle to realise widespread deployment for on-grid applications due to relatively high costs as well as questions related to the performance (lifespan, cycle performance) and the perceived safety risks associated with these systems. While the price of some battery technologies has rapidly declined, there is still a distance to go before they can achieve widespread deployment (EVI and IEA, 2013).

Current battery research is focused on new materials and chemical compositions that would enhance energy density and mitigate safety and environmental issues. In particular, manufacturing challenges with the assembly systems contribute to total system costs and introduce a significant opportunity area. At a minimum, these battery systems must achieve cost reductions to USD 1 000 per kilowatt (kW) by 2050 to achieve the deployment levels in the "breakthrough" scenario presented in this roadmap. However, it would be highly beneficial if this cost reduction target could be achieved earlier (by 2035).

Other current barriers include a lack of accessible system performance data with a contextualised cost and benefits analysis and a lack of widespread experience in managing these systems in the stakeholder community, as well as perceived safety concerns for some battery technologies. In the specific case of lithium ion batteries, significant cost reductions have been achieved, but additional reductions are needed to achieve widespread competitiveness. Demand for these batteries for EVs may provide an opportunity for accelerated cost reductions via mass production. Furthermore, EV batteries might be reused, finding second lives in stationary applications before ultimately being recycled. However, it is equally true that the weight and size considerations that play a primary role in EV battery technology development are not as important in stationary applications, so reductions in battery costs for EVs may not directly lead to increasing stationary use.

Box 12: Rare earth elements

Rare earth elements (REEs) are widely used in many energy storage technologies. Supply challenges for some of these materials (in particular dysprosium, neodymium, terbium, europium, and yttrium) result in a risk of supply interruptions in the short-term. In the longer term, efficient recycling of these materials can reduce the environmental impacts of REE mining and processing, and reduce the risk of supply disruptions from countries with large reserves to those with high demand. Recently, China has tightened its REE supply and some countries, including the United States, have instituted centralised efforts to recycle these materials (US DOE, 2012). Many countries already have successful battery recycling programmes to recover usable REEs and to reduce negative environmental impacts. For example, 96% of lead-acid batteries are recycled each year. Furthermore, new lead-acid batteries in the United States are made from 60% to 80% recycled materials (US EPA, 2012).

Long-term (hours-seasons) storage applications for arbitrage, load following, and other grid services

This roadmap recommends the following actions:	***Proposed timeline***
Assess and catalogue potential PSH and CAES sites and estimated costs. For PSH, this assessment should include pump-back, off-stream, and closed-loop, land-based and marine potential.	2014-20
Assess potential and costs of transforming existing constant-speed PSH into variable-speed, allowing these plants to provide additional ancillary services in both charging and discharging modes.	2014-20
Investigate the potential to improve total efficiency and flexibility in existing PSH facilities. Complete retrofits on systems that provide significant opportunity.	2014-20 (assess potential), 2020-35 (complete retrofits)
Improve the storage efficiency of CAES systems to approach 70%, particularly through improvements in compression (turbine) efficiency and adiabatic CAES project development.	2014-35

In addition to the battery technology recommendations presented in the previous section, this roadmap recommends additional actions for technologies that can support long-term storage applications. PSH and CAES technologies have significant potential as both bulk storage and to supply other services in the electricity grid. In Europe, it is estimated that PSH capacity could be increased by up to 10 times the current volume. (Gimeno-Gutiérrez and Lacal-Arántegui, 2013) Unfortunately, these technologies struggle from the high upfront investment costs due to large project sizes and – in some cases – geographic requirements that can further increase upfront costs.

Given the large potential role for these technologies, it is crucial that assessments be completed to identify suitable sites for new installations. In these evaluations, emphasis should be placed on seawater PSH and underground PSH in additional to conventional dam and run-of-river designs (IEA, 2012).[20] Underground PSH refers to systems where a well is drilled into underground reservoirs, allowing water to be pumped up into higher reservoirs (either other underground reservoirs or surface-level, man-made holding areas). This technology has shown promise in small to medium sized storage systems.

20. Run-of-river designs for hydropower facilities function similarly to conventional plants, except little or no water storage (reservoir) is incorporated.

In the case of PSH, with its current dominance in global long-term electricity storage, the large number of existing constant-speed storage systems also provides the opportunity to increase storage capabilities without the need for new facilities (IEA, 2012). This potential could be realised through the transformation of existing facilities into variable-speed systems where significant opportunities exist. These facilities could then better supply electricity grid support services, shortening the payback period for these large investments. The potential for these retrofits and the associated estimated costs should be identified and then completed as is seen fit.

For CAES technologies, new design proposals have the potential to reach efficiencies of up to 70% primarily through reducing natural gas use. However, these technologies have not been deployed at scale.[21]

21. See technical annex for more detail on these energy storage technologies. www.iea.org/publications/freepublications/publication/name,36573,en.html.

Thermal energy storage for low-temperature (<10°C) applications

This roadmap recommends the following actions:	***Proposed timeline***
Document and more effectively communicate the cost and performance of ice storage systems for cooling applications and best practices for installation and operation.	2014-20
Expand materials research and development activities related to PCMs for the transportation of temperature sensitive materials.	2014-30
Evaluate the potential to use current commercial refrigeration centres to provide demand response services through thermal energy storage and then retrofit these facilities as appropriate.	2014-30
Support the evaluation of the use of thermochemical energy storage systems for low-temperature applications.	2020-30

Demand for cooling will be a major global driver for increasing energy demand in the future, in particular in developing economies. Thermal energy storage can provide the means to temporally shift this increasing cooling demand, reducing the stress on the energy system. In the short term, ice storage systems represent a viable technology option for distributed thermal energy storage in many markets. Commercial refrigeration systems may also provide significant demand response services. The deployment of these technologies could be aided through transparent documentation and communication of current system cost and performance information, as well as the sharing of best practices for installation and operation.

In the medium term, PCMs for the transportation of temperature sensitive materials could reduce transportation fuel demand for refrigerated trucks. However, most technology options currently require further research, development and deployment efforts before widespread commercial deployment can be achieved.

In the long term, the energy density potential for thermochemical energy storage systems makes them an appealing option. However, it is still unclear what role they could play for low-temperature applications. This role should be analysed in the short term and then expanded.

Thermal energy storage for medium temperature (10°C to 250°C) applications

This roadmap recommends the following actions:	***Proposed timeline***
Improve the thermal and economic efficiency, and reliability of UTES systems at medium temperatures, including pit heat storage systems.	2014-20
Retrofit current electric water heaters and/or heat pumps – in particular in high concentration urban areas – to allow them to provide thermal energy storage demand response services, e.g. peak reduction and flexibility.	2014-25
Enhance the performance of sensible heat storage technologies by reducing heat losses and improving the stability of materials over time and in the presence of a high number of charging and discharging cycles.	2014-25
Reduce system costs and improve the performance of PCMs for solar installation temperature regulation (i.e. temperature regulation of PV to improve PV efficiency/ performance).	2014-30
Focus R&D to improve control technologies for use in advanced storage systems, including thermochemical storage technologies for medium temperature applications.	2020-35

Heating demand in buildings is a major peak energy driver in regions with a high number of heating degree days (IEA, 2011). In addition to cataloguing waste heat resources and potential applications, this roadmap recommends several technology-specific actions related to these types of medium temperature applications. In the short term, in addition to quantifying the energy storage potential in existing infrastructure, this roadmap recommends the rapid retrofit of current electric water heaters with water storage tanks to allow for their effective use in demand management (e.g. through timers and remote control). This action is likely to be most beneficial in urban areas that already have high concentrations of these systems.

The inclusion of PCMs for heat collection in solar installations could have the two-fold benefit of improving PV system efficiencies while also collecting usable energy for local storage and use. Key considerations for this and other building applications include storage density, containment vessel and system component designs and performance.

For large-scale thermal storage systems, UTES technologies benefit from naturally occurring cold and hot temperature resources. Today's systems, however, struggle with system efficiency and reliability at elevated temperatures. While some of this inefficiency is due to the thermodynamic constraints (i.e. the smaller temperature gradient over which the system might be operating), other inefficiencies lie in reliability decreases in the UTES system, which can be addressed.

In the longer term, thermochemical energy storage – with its high energy densities – should be developed for medium temperature applications. Some demonstration projects have already been completed in Germany and other countries, but development is still needed in these systems' control technologies (IEA ECES, 2011).

Thermal energy storage for high-temperature (>250°C) applications

This roadmap recommends the following actions:	*Proposed timeline*
Improve system concepts and operational characteristics of UTES systems in different geological conditions.	2014-25
Develop molten salts (or similar thermal energy storage materials) with lower melting temperatures, while maintaining their stability at higher temperatures for CSP applications to improve system efficiency.	2014-30
Focus R&D to improve the material stability and associated control technology of thermochemical storage systems for high-temperature applications (e.g. develop new containment vessels that perform well under significant temperature changes with peak temperatures exceeding 250°C).	2014-30
Improve the containment vessels and associated equipment used in PCM storage systems.	2014-35
Identify the potential environmental impacts of high-temperature UTES systems (e.g. impacts on geology, water quality) and ways to mitigate these impacts.	2020-30

In thermal energy storage, one prominent opportunity lies in improving the storage materials used in CSP applications. Today's molten salt mixtures remain stable at temperatures above 400°C, providing an advantage compared to oils used for similar applications. However, these mixtures typically solidify at temperatures below the 200°C to 250 °C range, resulting in significant energy requirements during the night-time to prevent damage from solidification when heat is not being collected. If these salts are allowed to solidify, serious mechanical problems will result. Therefore, preventing solidification at temperatures below 200°C represents a prime efficiency opportunity and could significantly reduce the costs of thermal storage in CSP facilities.

The high long-term potential for thermochemical energy storage to provide high-density, low-cost, and high-cycle energy storage makes it an attractive area for R&D. Currently, major challenges to thermochemical storage systems include material stability and containment, as well as the development of effective control technology. Once these issues are resolved, it will be easier to identify the ideal applications for these technologies; over the next decade, emphasis should be placed on materials research. Subsequently, emphasis should shift to rapidly applying these designs in demonstration projects (IEA ECES, 2011).

Advances in geothermal R&D activities could lead to improvements in system concepts and operation of UTES to overcome hydrogeological constraints and to prevent scaling and corrosion at high temperatures (EC, 2013).

Policy, finance, and international collaboration: actions and milestones

There are several drivers that support increasing use of energy storage technologies, including the movement toward decarbonisation, increasing energy access, greater emphasis on energy security, aging energy system infrastructure, and an emphasis on decentralised energy production, in part due to rapidly declining solar PV costs. At the same time, many factors influence the deployment of energy storage beyond technology cost and performance.

The widespread deployment of these technologies is particularly dependent on achieving acceptable cost recovery. Current policy environments and market conditions often cloud the cost of energy services, creating significant price distortions (e.g. by requiring generators to also supply power services without additional compensation, obscuring the cost of these additional services). In liberalised electricity markets, energy storage cannot receive direct payments for many of the benefits it provides (e.g. transmission investment deferral).

Unless compensation for energy storage system services is provided – or reliable cost recovery mechanisms are put in place – high levels of deployment will be difficult to achieve and storage technologies when competing with other options for system flexibility. A key to achieving widespread storage technology deployment is enabling compensation for the multiple services performed across the energy system. A patchwork approach to creating an energy storage market will not be able to capture the full value of energy storage technologies.

In unbundled electricity systems in particular, storage technologies frequently do not fit naturally into existing regulatory frameworks, as they provide value across different portions of the market (i.e. a single technology supports both the supply and demand sides, or transmission and distribution). Moreover, the current economic climate makes it difficult for organisations to invest in infrastructure projects, including energy storage. It also amplifies risk-averse inclinations of utilities, as well as existing inertia toward traditional supply technologies and grid management practices.

These factors emphasise the need for a focus on compensation as a function of the service provided by an energy system technology (e.g. payment based on the value of reliability, power quality, energy security and efficiency gains). They also signify areas where governments can actively support the accelerated deployment of energy storage.

Many governments have already acted publically in support of energy storage project development, through efforts such as direct financial support of demonstration projects, comprehensive market transformations, and mandates for energy storage projects (Table 9). Nonetheless, while many governments have made strides in supporting widespread adoption of energy storage technologies, there is still a great distance to go in accelerating their deployment.

These actions are interesting case studies for identifying global recommendations for policy actions and international collaboration. In particular, recent action in the United States reveals how a market-based approach can accelerate energy storage technology deployment on a large scale. In California, the state's Public Utility Commission has recently mandated the procurement of energy storage technologies. In 2013, Southern California Edison requested bids for 50 MW of new storage projects for the Los Angeles region and received more than 500 formal proposes. The German government's support of small-scale storage in support of distributed solar PV resources provides insight on the added value of distributed storage in a high renewable penetration environment. Japan's recent emphasis on time-shifting large amounts of energy demand using storage technologies also provides an interesting viewpoint on the potential for storage as a demand response tool.

Table 9: Examples of government actions that have positively supported energy storage technology deployment

Country or region	***Organisation and overview***	***Type of support***
Canada	Ontario Ministry of Energy ● The Ontario government will include storage technologies in its energy procurement process by the end of 2014. Initially, 50 MW of storage technologies will be installed to assist with the integration of intermittent renewable generation, optimise electric grid operation, and support innovation in energy storage technologies. ● Former standard offer feed-in-tariff procurement process for renewable generation projects (>500 kW) will be replaced with a competitive procurement model in Ontario. This new process will provide opportunities to consider systems that integrate energy storage with renewable energy generation.	Direct mandate, market evolution
China	Central government ● Financial support of demonstration projects including the Zhangbei project (36 KWh lithium-ion battery system) in Zhangbei, Hebei to evaluate the value of energy storage in providing electricity grid flexibility.	Demonstration project, performance testing
European Union	European Commission – Framework Research Programme (FP7) ● Co-funding (with the Intelligent Energy Europe Programme) of the stoRE project, with the goal of creating a framework that will allow energy storage infrastructure to be developed in support of higher variable renewable energy resource penetrations. Target countries include Spain, Germany, Denmark, Austria, and Ireland.	International collaboration, policy framework development
Germany	Federal government ● Support of RD&D in the framework of the energy research programme and in the framework of the "funding initiative storage" ● Financing of a website presenting progress of funded projects.	Support of RD&D documentation, public information
Germany	Federal Ministry of the Environment, Nature Conservation, and Nuclear Safety ● Subsidy for small-scale energy storage projects to encourage distributed energy storage deployment to complement high small-scale PV penetration (2013).	Direct subsidy for distributed storage
Japan	Ministry of Economy, Trade, and Industry ● Government support of energy storage projects to demonstrate the ability to time-shift demand by 10% in conjunction with expanded use of renewable generation resources. METI funding up to 75% of storage system cost with a goal of driving down total cost of USD 234/kWh within the next seven years.	Support of demonstration projects, performance documentation

Table 9: Examples of government actions that have positively supported energy storage technology deployment (continued)

Country or region	Organisation and overview	Type of support
South Korea	Ministry of Trade, Industry, and Energy (MOTIE) • Public funding of 4 MW Li-Ion battery demonstration projects, to be installed by the Korea Electric Power Corporation (KEPCO). Public funding of 8MW Li-ion battery for frequency control to be installed by Korea Power Exchange.	Support of demonstration project, performance documentation
United States	California Public Utilities Commission • Requiring the state's three largest utilities to invest in over 1.3 GW of new energy storage capacity by 2020. FERCs – Orders 755 and 784 • Taking proactive steps to open United States electricity markets to energy storage technologies • Permitting companies other than large utilities to sell ancillary services in the electricity market • Recognising value of super-fast response technologies, including energy storage. Requires operators to compensate for frequency regulation based on the actual service provided. Department of Energy • Global Energy Storage Database.	Direct mandate, market evolution, price distortion reduction, international collaboration

In supporting energy storage, this roadmap recommends that policies avoid a primary focus on targeted storage technology mandates. Within these policies, regional dynamics such as variable renewable energy and waste heat resource availability, policy and social development goals, and energy demand profiles should be taken into consideration, including the current energy system technology profile and resources.

The ability of storage deployment to be purely market-driven is greatly inhibited by a lack of price transparency, high upfront investment costs (at times), and significant price distortions in energy markets. Some potential mechanisms for addressing this problem include real-time pricing, pricing by service, and taxation being applied to final products (versus on supply of energy into storage units). Furthermore, governments should support the inclusion of energy storage technologies as tools for supplying energy and power services in environments that are less market-driven, and fund R&D programmes to develop these technologies for their region's specific needs.

In addition to high-level policies that support low-carbon transitions, policies should allow for the compensation of services provided by energy storage technologies throughout the energy system. This should include the identification and elimination of price distortions in energy markets that create an artificial negative cost impact on energy storage technologies. It is recommended that compensation be given directly for individual services, which is already the case in some markets.

Furthermore, policies should also enable benefits-stacking by energy storage operators, which has been shown in multiple studies to significantly improve the business case for energy storage projects (ESA, 2011 and BNEF, 2013). These studies could be recognised in markets and also in business cases, based on the documented cost and benefit value that can be presented to utility regulators. For example, in the United Kingdom the annual cost of storage systems is expected to be lower than the total benefit of the short-term and fast reserve services they supply (BNEF, 2013).

Policy and regulatory frameworks

This roadmap recommends that the following actions be taken:	***Milestone***
Eliminate price distortions and increase price transparency for power generation and heat production, e.g. time-of-use pricing schemes, pay-for-services (heating, cooling, quick response, etc.) models.	2020
Enable benefits-stacking for energy storage systems.	2020
Government support of energy storage use in off-grid and remote communities.	2025
Support of the rapid retrofit of existing energy storage facilities to increase efficiency and flexibility, where these retrofits appear warranted.	2030
Inclusion of energy storage technologies as options for supplying energy and power services, and support for their continued development through government-funded R&D programmes.	2030

These studies can also be used for the benefit of systems that are less market-driven, quantitatively justifying policies allowing for the addition of energy storage technologies.

Recent action in the United States, under FERC Orders 755 and 784, provide evidence of how access to ancillary service markets can positively influence storage project proposal economics. However, it is yet to be seen if these efforts will be sufficient to support the entire suite of electricity and thermal storage technologies currently available to provide energy system support services.

In the shorter term, policies should encourage energy storage deployment in off-grid and remote communities where energy storage technologies are already broadly competitive or near-competitive. In these cases, third-party verification of energy storage project performance could become prime case studies for later implementation in other geographies. Furthermore, off-grid areas in developing economies provide an additional opportunity for energy storage demonstration projects and case study development. These locations also introduce the opportunity for incremental gains through increased production values.

For existing centralised storage facilities, efforts should be made to increase their efficiency and flexibility, improving their potential to support increasing levels of variable renewable generation and to optimise energy exchanges within both the electricity grid and dedicated heat networks. For existing demand-side infrastructure, governments should support the inventorying and utilisation of existing – primarily thermal – distributed storage capacity. A common drawback of these systems is the currently limited feedback to users regarding the system's performance. Improved statistics and efficiency labelling schemes for energy storage could increase storage deployment and use. For example, in the use of residential hot water heaters and commercial refrigeration centres for demand response, better matching of supply and demand curves could result in significant efficiency (and carbon emissions reduction) gains.

In the longer term, policies should be geared toward incentivising storage technologies based on the applications they are used for in the energy system. The development of breakthrough energy storage technologies should also be supported by policies that endorse financing of innovative research, development, and demonstration projects. While specific technology actions were previously discussed, it is noted here that governments can play a key role in the collection and dissemination of lessons learned from demonstration projects. These efforts may expand upon those already initiated by other government organisations.[22]

22. For example, the US Department of Energy's Global Energy Storage Database.

Incentivising investment

This roadmap recommends that the following actions be taken:	*Milestone*
Facilitate entry into, and exit from, energy markets from the supply through demand portions of the energy system: e.g. through ancillary service markets and tariff structures to support distributed energy storage systems.	2015
Clarify energy storage's role in the energy system, e.g. through defining ownership structures and ownership eligibility.	2018
Streamline the financing process for new large-scale storage systems, with clear guidelines on documentation requirements.	2018
Incentivise the co-financing of distributed electricity generation technologies with integrated storage after assessing the risks and benefits of this approach.	2020
Targeted support for energy storage demonstration projects and financial support of early movers for new commercial-scale projects (e.g. through risk guarantee schemes).	2025

While policy and regulatory reform can create a more attractive environment for energy storage investments, further action is needed to incentivise widespread investment. Efforts should especially be made to clarify ownership structures in ways that enable energy storage technologies to be used for a wide array of applications over time.

Furthermore, both large- and small-scale storage systems would benefit from more transparent means for securing financing. For large-scale projects, the process of securing financing should be streamlined, with requirements for the information needed to successfully support financing attempts. For small-scale (distributed) storage resources, there would be many benefits from co-financing opportunities for new generation resources with integrated storage (e.g. residential PV systems with onsite battery storage, or wall heaters with thermal storage).

Easy entry into, and exit from, energy markets is also a key to incentivising investment, allowing new companies to supply energy and power services in the market. This ease will allow for new technologies to progress more rapidly across development "valleys of death" – to move from the lab bench to commercial markets. On the demand side of the energy system, the adoption of tariff structures or programmes capable of revealing the value of particular services might help support distributed energy storage systems (e.g. in homes and office buildings) and help catalyse customer adoption and use of these technologies.

Another key component in moving suitable technologies more quickly from laboratory to widespread commercial deployment lies in targeted financial support in demonstration projects, as well as risk guarantee schemes (in particular for large-scale storage projects). By supporting key demonstration projects, governments can not only help move technologies along the development path but also gain useful data and knowledge of best practices that can be applied in widespread deployment efforts.

Planning and permitting

This roadmap recommends that the following actions be taken:	*Milestone*
Develop a widely accessible clearinghouse for energy storage project information and other data needed to support project proposal evaluations.	2020 (existing), ongoing to 2050 (new projects)
Streamline the siting and permitting process for new centralised energy storage projects, in particular for UTES systems.	2025

Two primary barriers exist to widespread energy storage technology deployment in terms of project planning and permitting. First, the lack of a widely accessible clearinghouse for energy storage project information inhibits project proposal development. This information should go beyond technical performance and cost data to include best practices and operational lessons learned. Furthermore, today's siting and permitting processes for new energy storage projects can be quite long and cumbersome. Similar to energy supply infrastructure permitting processes, this complexity adds significantly to total project costs in many cases. Current regulatory barriers to increased use of groundwater for UTES systems should be evaluated and updated. This problem should be addressed through a streamlining of siting and permitting processes to provide clarity in the expectations for new energy storage system projects.

Training and public engagement

This roadmap recommends that the following actions be taken:	*Milestone*
Develop improved workforce training programmes with customised course content pertaining to energy storage technologies.	2018
Further develop international standards and testing programmes to document safety and performance of energy storage technologies.	2018
Develop and implement programmes to increase the utilisation of distributed demand-side energy storage capacity (i.e. residential water heaters with timers and remote control capabilities to shift demand from peak to off-peak periods).	2020

Some energy storage technologies are covered by recognised international standards, which simplify system procurement, installation and operation. Other technologies (e.g. batteries) may be subject to inappropriate standards, because the standard-making process has not kept up with the rate of technical development. For technologies that are on the brink of commercial viability, this roadmap recommends widespread support through the development of standards and operation protocols,[23] workforce training programmes, performance and safety testing, and consumer awareness programmes. Combined, these actions will help to overcome NIMBYism and other consumer acceptance hurdles. These international standards should be established in a manner that allows for easy updating with technology advancements.

Performance and safety testing can particularly help in overcoming both supply-side and demand-side consumer acceptance of storage technologies, as well as improve access to financing. Actions should be taken to test and document performance and safety records for energy storage technologies as they reach commercial maturity. Furthermore, for storage technologies with high levels of deployment potential, any safety risks that are identified in these testing procedures should lead directly to targeted R&D efforts.

For distributed demand-side energy storage capacity in existing infrastructure (e.g. residential hot water heaters), experiences in France (among other countries) have shown how consumer awareness programmes can significantly improve adoption rates. Combined with the previous recommendation to eliminate energy market price distortions, consumer awareness campaigns will help increase utilisation factors for these storage assets.

23. by organisations including the International Organization for Standardization (ISO).

International collaboration

This roadmap recommends that the following actions be taken:	*Milestone*
Designate innovation "free" zones to facilitate the testing of storage technologies in the absence of complex markets and policy structures.	2020
Promote knowledge sharing through the development of an international energy storage project database and production databases for energy supply and demand curves with high levels of granularity.	2030 (ongoing to 2050)

In a global transition to a decarbonised energy system, many opportunities exist for international collaboration. Countries and regions with significant experience evaluating energy storage technologies can provide guidance for new market participants. Developing economies could provide opportunities for the development of innovation "free" zones (i.e. "free" of non-technical barriers), where new technologies may be tested in the absence of distorting policies and other energy system complexities. However, market exposure is highly needed for energy storage technologies to achieve widespread deployment. Demonstration projects should therefore not be limited to these "free" zones, as described in the previous section.

Perhaps most significant is the opportunity for knowledge sharing through the development of an international energy storage project database and production databases for energy supply and demand curves. This type of collaborative effort would greatly enhance technical and market analysis for new storage technology proposals, and if continually updated over time, opportunities for research and future development will present themselves. The US Department of Energy has made significant progress in establishing such a database with their "Global Energy Storage Database" website, but more input from other countries is needed.

In addition, several multilateral initiatives have emerged in recent years to facilitate collaboration on storage technology, including the ECES IA. In the European Union, the EASE and the European Technology Platform on Renewable Heating and Cooling are examples of collaborative initiatives that are striving to encourage accelerated energy storage technology development and deployment.

Conclusion: near-term actions for stakeholders

This roadmap responds to requests for deeper analysis on the role energy storage technologies can play in the transition of our energy system. It is intended to outline the various applications of electric and thermal storage technologies, particularly within the electricity system. The roadmap has been designed with milestones that the international community can use to measure progress and assess efforts to ensure that energy storage development is on track to achieve the emissions reductions required by 2050.

Below is a summary of near-term actions needed by energy storage stakeholders, presented to indicate who should take the lead in specific efforts. In most cases, a broad range of actors will need to participate in each action. The IEA, together with government, industry and non-governmental organisation (NGO) stakeholders, will report on this progress and recommend adjustments to the roadmap as needed.

Lead stakeholder	Actions
Governments	• Create an accessible global dataset of energy storage technology project overviews, including information on system specifications, cost and performance. Establish international and national data co-operation to foster energy storage research, monitor progress, and assess the R&D bottlenecks. • Compile a comprehensive dataset of renewable generation production behaviour with high levels of granularity to allow for assessment across a wide range of energy storage technology applications through the year. • Support materials research and efficiency gains via mass production for battery systems to improve energy density and reduce costs. • Develop improved workforce training programmes with customised course content pertaining to energy storage technologies. • Streamline the siting and permitting process for new energy storage projects. • Implement testing programmes to document the safety and performance of energy storage technologies, based on published standards and protocols. • Eliminate price distortions and increase price transparency for power generation and heat production, including time-of-use pricing and pay-for-services models.
Industry	• Quantify waste heat availability and opportunities, including details on waste heat quantity, quality and location for both resources and potential demand. • Quantify distributed energy storage potential in existing infrastructure. • Assess global energy storage potential by region for capital-intensive projects, including PSH, CAES and UTES. • Document and more effectively communicate the cost and performance of ice storage systems for cooling applications and best practices for installation and operation. • Improve battery assembly design to improve system reliability and performance. • Demonstrate energy storage system performance in the context of multiple applications and share results with stakeholder community. • Improve operation management of battery systems, both centralised and distributed. • Retrofit existing energy storage facilities to increase efficiency and flexibility. • Explore new business models to overcome the barrier of high upfront costs of innovative and efficient energy storage solutions.

Lead stakeholder	Actions
Universities and other research institutions	• Accelerate R&D efforts focused on optimising the integration of energy storage technologies in the energy system. • Improve thermal efficiency and reliability of UTES systems at elevated temperatures. • Develop molten salts (or similar thermal energy storage materials) with lower melting temperatures while maintaining their stability at higher temperatures. • Improve containment vessels and associated equipment used in PCM storage systems. • Improve the efficiency of supercapacitors and document technology performance through testing and demonstration.
Financial institutions	• Streamline the financing process for new large-scale storage systems, with clear guidelines on documentation requirements. • Incentivise the co-financing of distributed electricity generation technologies with integrated storage after assessing the risks and benefits of this approach.
Non-governmental organisations	• Implement consumer awareness campaigns to increase utilisation of distributed demand-side energy storage capacity (e.g. residential hot water heaters for peak demand reduction). • Work with standard–setting organisations and governments to develop performance-based labelling of energy storage.

Annexes

Annex A: Energy storage technology

www.iea.org/publications/freepublications/publication/name,36573,en.html

Annex B: Analytical approach

www.iea.org/publications/freepublications/publication/name,36573,en.html

Acronyms, abbreviations and units of measure

Acronyms and abbreviations

2DS	2°C Scenario in *Energy Technology Perspectives 2014*
ATES	aquifer thermal energy storage
BTES	borehole thermal energy storage
CAES	compressed air energy storage
CCS	carbon capture and storage
CHP	combined heat and power
CO_2	carbon dioxide
CSP	concentrating solar power
EASE	European Association for Storage of Energy
ETP 2014	*Energy Technology Perspectives 2014*
FERC	US Federal Energy Regulatory Commission
GHG	greenhouse gas
KEPCO	Korea Electric Power Corporation
Li-ion	lithium-ion
NaS	sodium-sulphur
NDRD	National Development and Reform Commission
NIMBY	not in my backyard
PCM	phase-change material
PJM	Pennsylvania-New Jersey-Maryland Interconnection
PSH	pumped-storage hydropower
PUCT	Public Utility Commission of Texas
PV	photovoltaic
R&D	research and development
RD&D	research, development and demonstration
REE	rare earth elements
RTO	regional transmission organisation
SGERI	State Grid Energy Research Institute
SMES	superconducting magnetic energy storage
TES	thermal energy storage
UHV	ultra high voltage
UTES	underground thermal energy storage

Units of measure

°C	degree Celsius
GW	gigawatt
GW_{el}	gigawatt electrical capacity
GWh	gigawatt hour (10^9 watt hour)
kcal	kilocalories (10^3 calories)
kg	kilogramme (10^3 grammes)
kV	kilovolt
kW_{el}	kilowatt electrical capacity
kWh	kilowatt hour (10^3 watt hour)
m^3	cubic metre
MWh	megawatt hour (10^6 watt hour)
MW	megawatt (10^6 watt)
s	second
TWh	terawatt-hour

References

Battke, B., T.S. Schmidt, D. Grosspietsch and V.H. Hoffmann (2013), “A review and probabilistic model of lifecycle costs of stationary batteries in multiple applications”, *Renewable and Sustainable Energy Reviews* Vol. 25, pp. 240-250.

Beier, P. and P. Bretschneider (2013), “Modellbasierte, regional aufgelöste Analyse des Bedarfs an netzgekoppelten elektrischen Energiespeichern zum Ausgleich fluktuierender Energien“, final report, Bedarfsanalyse Energiespeicher, Frauenhofer Institute, Munich, Germany, www.iosb.fraunhofer.de/servlet/is/37913/04_IOSB_Jahresbericht-2012-2013_Standorte2.pdf.

Black & Veatch (2012), “Cost and performance data for power generation technologies”, *Cost Report*, February, Black & Veatch, Overland Park, Kansas, United Sates.

BMU (Federal Ministry for the Environement, Nature Conservation and Nuclear Safety) (2012), “Langfristszenarien und trategien fur den Ausbau der erneuerbaren Energien in Deutschland bei Berucksichtigung der Entwicklung in Europa und global”, BMU, Berlin, Germany.

BMWI (Federal Ministry for Economic Affairs and Energy) (2013), “Gesamtausgabe der Energiedaten - Datensammlung des BMWi”, *Sheet 22*, (database) August 20 update, Berlin, Germany, www.bmwi.de/BMWi/Redaktion/Binaer/energie-daten-gesamt,property=blob,bereich=bmwi2012,sprache=de,rwb=true.xls.

BNEF (Bloomberg New Energy Finance) (2013), “Views on the Role of Energy Storage” presented at the IEA (International Energy Agency) Energy Storage Technology Roadmap Stakeholder Engagement Workshop, Paris, France, 13 February.

Decourt, B. and R. Debarre (2013), “Electricity storage”, *Factbook*, Schlumberger Business Consulting Energy Institute, Paris, France.

Denholm, P. (2013), personal communication, 25 September.

Droste-Franke, B. (2013), “Future storage and balancing demand: ranges, significance and potential improvements of estimations”, presented at the 8th International Renewable Energy Storage Conference and Exhibition (IRES 2013), Berlin, 18 November.

EASE (European Association for the Storage of Energy) and EERA (European Energy Research Alliance) (2013), “Joint EASE/EERA recommendations for a European Energy Storage Technology Development Roadmap towards 2030”, EASE/EERA, Brussels, Belgium.

EC (European Commission) (2013), “Strategic research and innovation agenda for renewable heating & cooling”, *European Technology Platform on Renewable Heating and Cooling*, Publications Office of the European Union, Luxembourg, Luxembourg.

Ecofys and Bonneville Power Administration (2012), “TI 220 project evaluation report ”, September, Ecofys and Bonneville Power Administration, Corvallis and Portland. OR, United States.

EIA (Energy Information Administration) (2012), “Electricity storage: Location, location, location….. and cost”, *Today in Energy,* Washington, DC, United States, www.eia.gov/todayinenergy/detail.cfm?id=6910.

EPRI (Electric Power Research Institute) (2010), “Electrical Energy Storage Technology Options”, Report, EPRI, Palo Alto, CA, United States.

ETT (Electricity Transmission Texas) (2013), “Electric transmission Texas brings largest utility-scale battery in the United States to one of oldest cities in Texas”, PR Newswire, 8 April, New York.

EIA (Energy Information Administration) (2013), *Annual Energy Outlook,* Washington, DC

Enerdata (2011), *Odyssee, the Europe Energy Efficiency Project*, (database), Grenoble, France, http://enerdata.net/enerdatauk/solutions/data-management/odyssee.php.

ERCOT (Electric Reliability Council of Texas) (2008), *ERCOT Board of Directors Meeting*, 15 July, Taylor, TX, United States.

ESA (Electricity Storage Association) (2011), “Energy storage benefits: benefits stacking”, ESA, Washington, DC, United States, www.electricitystorage.org/technology/energy_storage_benefits/benefits_stacking.

Eurelectric (2009), “Statistics and prospects for the European electricity sector (1980-2000, 2004, 2005, 2006, 2010-2030)”, *EURPROG 2008,* Eurelectric, Brussels, Belgium.

EU (European Union) (2012), “Energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC”, *Directives*, Office Journal of the EU, Brussels, Belgium.

EVI (Electric Vehicles Initiative) and IEA (International Energy Agency) (2013), *Global EV Outlook*, Paris, France.

Eyer, J. and G. Corey (2010), *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide,* Sandia National Laboratory, Albuquerque, NM, United States.

Gimeno-Gutiérrez, M. and R. Lacal-Arántegui (2013), “Assessment of the European potential for pumped hydropower energy storage”, European Commission Joint Research Centre (JRC), *Scientific and Policy Reports*, Brussels, Belgium, http://ec.europa.eu/dgs/jrc/downloads/jrc_20130503_assessment_european_phs_potential.pdf.

Hauer, A., J. Quinnell and E. Lävemann (2013), *Energy Storage Technologies - Characteristics, Comparison, and Synergies*, Wiley-VCH Verlag GmbH & Co., Weinheim, Germany.

Hercberg, S. (2013), Personal communication.

IEA (International Energy Agency) (2014a), *Energy Technology Perspectives,* forthcoming, OECD/IEA, Paris, France.

IEA (2014b), *The Power of Transformation: Wind, Sun and the Economics of Flexible Power Systems*, OECD/IEA, Paris, France.

IEA (2012), *Technology Roadmap: Hydropower,* OECD/IEA, Paris, France.

IEA (2011), *Technology Roadmap: Energy Efficient Buildings: Heating and Cooling Equipment,* OECD/IEA, Paris, France.

IEA (2010), *Technology Roadmap: Concentrating Solar Power,* OECD/IEA, Paris, France.

IEA and Energy Research Institute (2011), *Technology Roadmap: China Wind Energy Development Roadmap 2050*, OECD/IEA, Paris, France.

IEA Energy Conservation through Energy Storage (ECES) (2011), *Sustainable Cooling with Thermal Energy Storage,* final report, Annex 20, November, www.iea-eces.org/files/annex20_finalreport_combined_nov4th_2011.pdf.

IEA-ETSAP (Energy Technology Systems Analysis Programme) and IRENA (2013), “Thermal Energy Storage”, *Technology Brief E17*, Bonn, Germany.

IEA-ETSAP and IRENA (International Renewable Energy Agency) (2012), “Electricity Storage”, *Technology Policy Brief* E18, Bonn, Germany.

Konidena, R. (2013), “Working Group 7 – 2012 Final Report on Energy Storage” presented at the IEA Energy Storage Technology Roadmap Stakeholder Engagement Workshop, Paris, France, 14 February, www.iea.org/media/freepublications/technologyroadmaps/6GO15WG7PresentationIEAworkshop.pdf.

NETL (National Energy Technology Laboratory) (2010), “Life cycle analysis: supercritical pulverized coal (SCPC) power plant", NETL, September, Pittsburgh, United States.

NETL (2009), “Estimating freshwater needs to meet future thermoelectric generation requirements”, NETL, September, Pittsburgh, United States.

NREL (National Renewable Energy Laboratories) (2013), *Renewable Electricity Futures Study (RE Futures)* Golden, CO, United States, www.nrel.gov/analysis/re_futures/.

O’Donnell, A. and K-A. Adamson (2012), *Thermal Storage for HVAC in Commercial buildings, District Cooling and Heating, Utility and Grid Support Applications, and High-Temperature Storage at CSP Facilities*, Pike Research, New York, United States.

Paksoy, H. (2013), “Thermal energy storage today” presented at the IEA Energy Storage Technology Roadmap Stakeholder Engagement Workshop, Paris, France, 14 February.

PJM Interconnection (2010), “Limited energy resources in capacity markets: problem statement”, paper prepared for August 5 meeting, Audubon, PA, United States, www.pjm.com/~/media/committees-groups/committees/mrc/20100805/20100805-item-10b-limited-energy-resources.ashx.

Rastler, D. (2011), *Midwest Independent Transmission System Operator (MISO) Energy Storage Study Phase 1 Interim Report, EPRI,* Palo Alto, United States, November,
www.uwig.org/miso_energy_storage_study_phase_1_report.pdf.

Reske, H.J. (2010), “Texas pioneers energy storage in giant battery”, *National Geographic*, 25 March, Washington, DC, United States.

S&C Electric (2013), "The Role of Energy Storage in Smart Microgrids", White paper, July, S&C Electric, Chicago, www.sandc.com/edocs_pdfs/edoc_076176.pdf.

Sandia National Laboratories (2010), *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide, A Study for the DOE Energy Storage Systems*, Albuquerque, NM and Livermore, CA.

Sandia National Laboratories (2011), "Power Tower Technology Roadmap and Cost Reduction Plan", Albuquerque, NM and Livermore, CA, United States, http://prod.sandia.gov/techlib/access-control.cgi/2011/112419.pdf#page19.

State Grid Energy Research Institute (SGERI) and Energy Research Institute (ERI) (2014), *2050 High Renewable Energy Scenarios for China*, forthcoming, Beijing, China.

THEMA (2013), "Loop Flows – Final Advice", *Thema Report*, Thema Consulting Group, Oslo, http://ec.europa.eu/energy/gas_electricity/studies/doc/electricity/201310_loop-flows_study.pdf.

US DOE (United States Department of Energy) (2013), *DOE Global Energy Storage* (database), www.energystorageexchange.org, (accessed in 2013).

US DOE (2012), *Critical Materials Strategy,* report, US DOE, Washington, DC, United States, http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf.

US EPA (Environmental Protection Agency) (2012), "Batteries: Just the Facts", November, Washington, DC, United States, www.epa.gov/osw/conserve/materials/battery.htm.

Ying, J. (2011), "The future of energy storage technologies and policy", *Bloomberg New Energy Finance (*database), (accessed on 12 April 2013).

Zucker, A., T. Hinchliffe, and A. Spisto (2013), "Assessing Storage Value in Electricity Markets", *Joint Research Centre (JRC) Scientific and Policy Reports*, Petten, The Netherlands.

IEA Publications, 9 rue de la Fédération, 75739 PARIS CEDEX 15
TYPESETTED AND PRINTED IN FRANCE BY IEA, MARCH 2014

Technology Roadmap Energy Storage

2014

2015

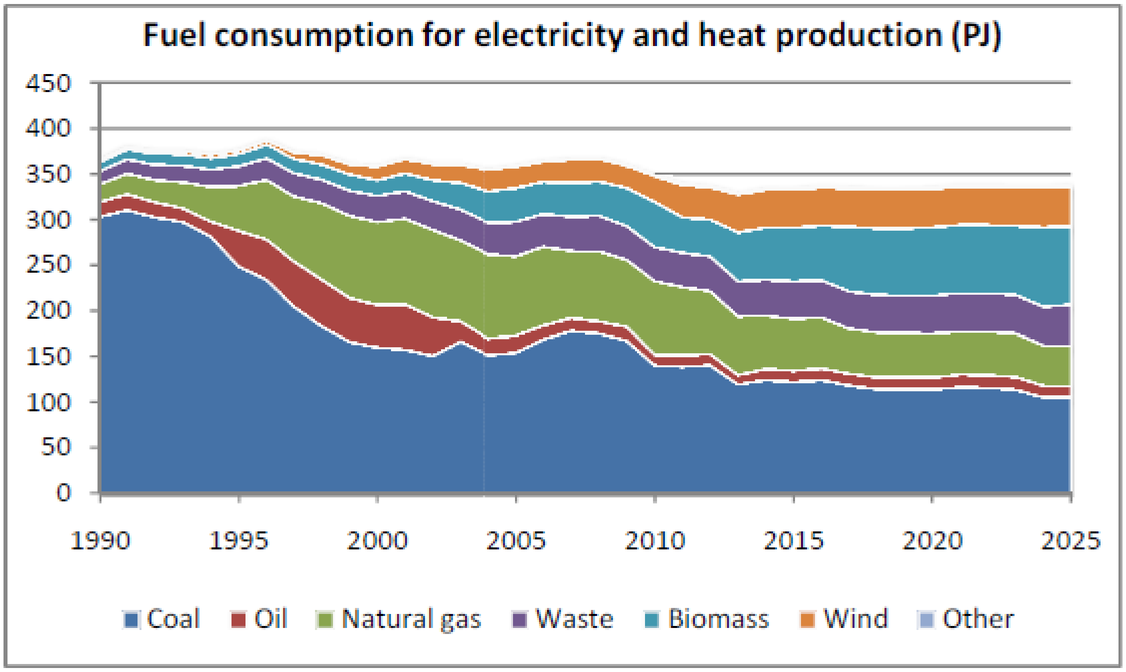
2020

2025

2030

International Energy Agency – IEA
9 rue de la Fédération, 75015 Paris, France
Tel: +33 (0)1 40 57 65 00/01, Fax: +33 (0)1 40 57 65 59
Email: info@iea.org, Web: www.iea.org

Exhibit “L”



Energi Styrelsen, Danish Energy Outlook, dated May 2011, online: <http://www.ens.dk/sites/ens.dk/files/info/facts-figures/scenarios-analyses-models/scenarios/Danish%20Energy%20Outlook%202011.pdf> at page 20.

Exhibit “M”

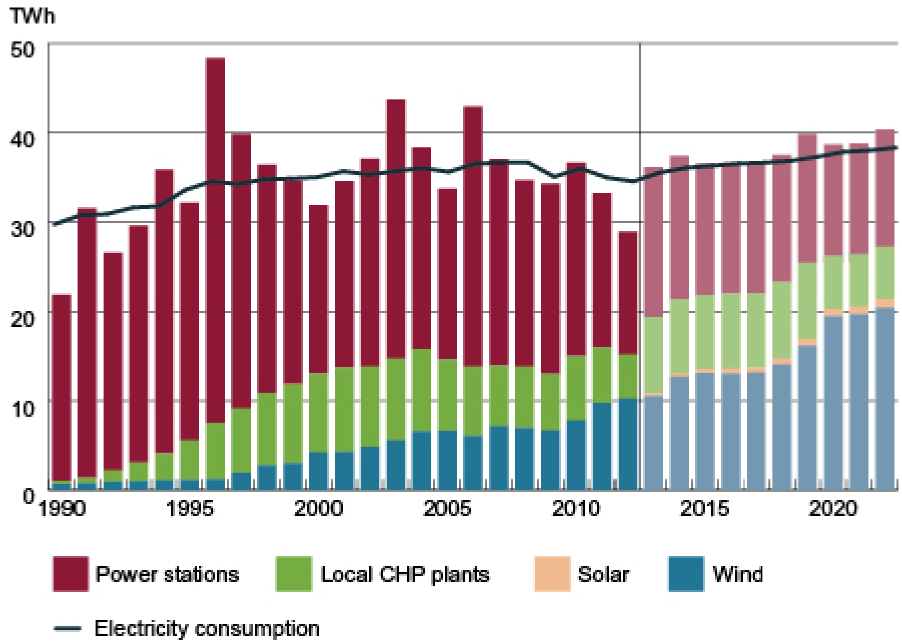


Figure 1 - Power consumption and generation in Denmark

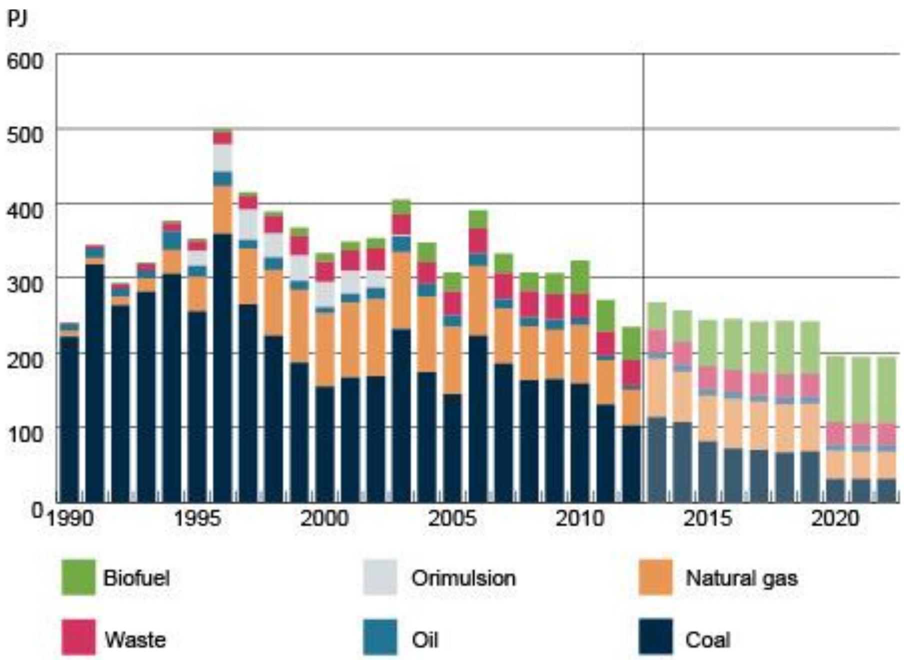
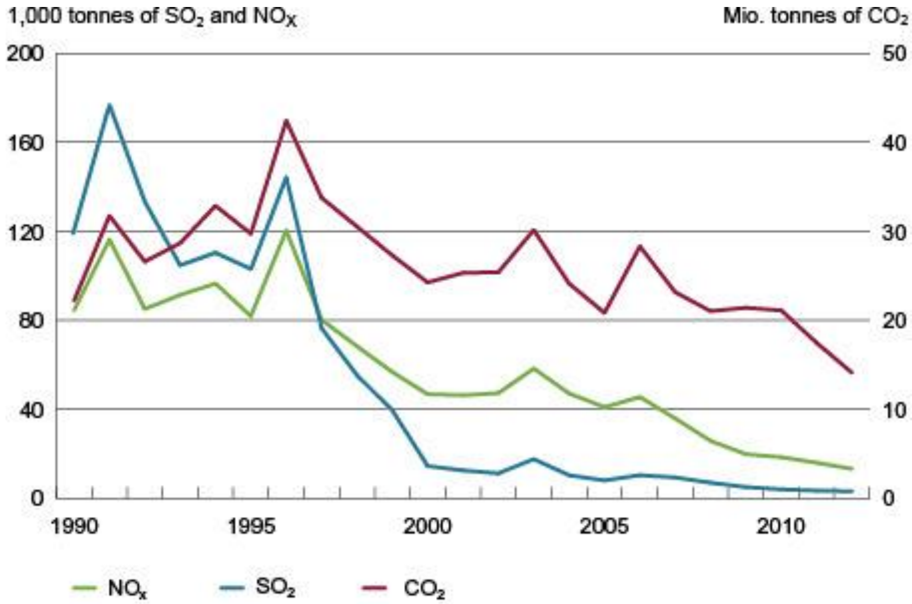


Figure 2 - Fuel consumption in Denmark

Energinet.dk, Environmental report for Danish electricity and CHP – summary of the status year of 2012, online: <https://www.energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Klimaogmiljo/Environmental%20report%20for%20Danish%20electricity%20and%20CHP%20-%20summary%20of%20the%20status%20year%202012.pdf>

Exhibit “N”



Energinet.dk, Environmental report for Danish electricity and CHP – summary of the status year of 2012, online: <https://www.energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Klimaogmiljo/Environmental%20report%20for%20Danish%20electricity%20and%20CHP%20-%20summary%20of%20the%20status%20year%202012.pdf>

Exhibit “O”

Million Tonnes of Green House Gas Emissions

Ontario			
	2012	**%**	**Mt of GHGs per 1 million households***
Buildings	28.39	17%	5.793877551
Electricity	15.03	9%	3.067346939
Transportation	56.78	34%	11.5877551
Agriculture, industry and waste	66.71	40%	13.61428571
Total Emissions	**167**	**100%**	**34.06326531**

Denmark			
	2013	%	**Mt of GHGs per 1 million households***
Buildings (Households, commercial, public and district heating)	6.799	16.34%	2.518148148
Households	2.576	6.19%	0.954074074
Commercial and public services	0.731	1.76%	0.270740741
District heating production	3.492	8.39%	1.293333333
Electricity production	13.273	31.91%	4.915925926
Transport	14.09	33.87%	5.218518519
Agriculture, gas production and industry	7.492	18.01%	2.774814815
Total Emissions	**41.6**	**100%**	**17.94555556**

***Based on 4.9 million households for Ontario and 2.7 million households for Denmark**

** Numbers used in the table are from Ontario's Climate Change Update 2014 (page 7) https://dr6j45jk9xcmk.cloudfront.net/documents/3618/climate-change-report-2014.pdf and the Danish Energy Agency Energy Statistics 2013 (page 39) http://www.ens.dk/sites/ens.dk/files/info/tal-kort/statistik-noegletal/aarlig-energistatistik/energystatistics2013.pdf