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TECHNICAL NOTE: ENERGY METRICS FOR CLEAN ENERGY MINISTERIAL INITIATIVES

Global Efficiency Challenge

End-use energy efficiency is a large and largely-untapped low-cost energy resource. The International Energy Agency's *World Energy Outlook 2009* estimates (in their "450 Scenario") that cost-effective energy efficiency measures could reduce global annual primary energy demand by 14% and oil demand by 15% (about 5.5 billion barrels) below business-as-usual by 2030. These measures would require an average incremental investment of $185 billion/year over the next decade and $630 billion/year over 2021-2030, and have a net present value of $8.6 trillion at a 3% discount rate.

Efficiency measures in buildings (including appliances), industry, and transport can avoid about 2.3 billion tons/year of CO_2 emissions by 2020 and 7.1 billion tons by 2030 – as much as would be produced by about 760 and 2,370 mid-size coal power plants, respectively.[1] They account for more than half of the carbon emissions savings needed over the next two decades in order to place the world on a cost-effective path toward a 450 ppm CO_2-equivalent greenhouse gas stabilization target.

The Global Efficiency Challenge aims to catalyze these investments. It has a goal of reducing annual energy consumption by the equivalent of the energy produced by 500 mid-size coal power plants (500 Rosenfelds) by 2030, for an estimated annual savings in 2030 of about $45-$90 billion/year.[2]

Table 1. *Bottom-up analyses of components of the SEAD and GSEP initiatives within the Global Efficiency Challenge estimate that annual energy savings resulting from those initiatives could total 865 to 1,848 Rosenfelds, which we conservatively rounded down to get the aforementioned 500 Rosenfelds. Other initiatives, such as that for smart grids and the cross-sectoral technology task groups of GSEP, will unlock additional savings, as addressed below.*

INITIATIVE	**BOTTOM-UP ESTIMATE OF ANNUAL ENERGY SAVINGS BY 2030* (In Terms of Rosenfelds)**
SEAD	300 to 1300
GSEP	500*
TOTAL	800 to 1800

* GSEP estimate is for 2025, not 2030; impact is expected to increase substantially through 2030

Appliances, Buildings and Industry

The IEA's 450 Scenario projects reductions in energy demand in the buildings sector (including appliances) by 10% below business-as-usual (1,460 Rosenfelds) and in the industrial sector by 15% below business-as-usual (2,010 Rosenfelds) by 2030. These reductions require an average investment of about 4 cents per kWh saved over the next two decades; assuming an average cost of generated electricity of about 7-10 cents per kWh, these investments yield a net savings of about 3-6 cents per kWh conserved – approximately $300-$600 billion/year in 2030. The Global Efficiency Challenge addresses these sectors through the SEAD and GSEP programs described below, as well as through synergies with ISGAN program, which address smart grids.

[1] A "mid-size coal power plant" refers to a 500 MW coal power plant, using the definition of the Rosenfeld unit for energy savings by Koomey et al., 2010, Defining a standard metric for energy savings, *Env. Res. Lett.* 5:014017. 1 Rosenfeld = 3.07 TWh/year generation = 2.87 TWh/year consumption = 3.01 Mt/year CO_2 emissions.
[2] In the event that economies accounting for more than 70% of global energy consumption participate in SEAD and ISGAN, this goal can be raised to 1,000 Rosenfelds.

Super-efficient Equipment and Appliances Deployment (SEAD) initiative: Based on a bottom-up analysis of equipment efficiency levels that are currently available and cost-effective or likely to become so by the time of program implementation, Lawrence Berkeley National Laboratory (LBNL) estimates that broad global energy efficiency efforts using tools such as standards, labeling and incentives could reduce demand by 1,610 TWh/year (560 Rosenfelds) in 2020 and 3,790 TWh/year (1,320 Rosenfelds) in 2030, yielding net savings of about $50-$100 billion/year in 2020 and about $115-$230 billion/year in 2030 (Table 2).[3] SEAD will tap into this potential both by coordinating standards, labeling and incentive programs among participating major economies and by developing policy toolkits that can be deployed both by these economies and in other countries.

As a specific example, preliminary LBNL estimates indicate that aggressive SEAD-coordinated appliance efficiency incentive programs, focused only on televisions, lighting, refrigerators, air conditioning and standby power, could potentially reduce global electricity demand by about 966 TWh/year (337 Rosenfelds) in 2030, for net savings of about $29-$58 billion/year.[4] These estimates assume that incentive programs deliver a 33% efficiency improvement above business-as-usual in 50% of all new products sold globally. By comparison, in the U.S., Energy Star products a typically 20%-30% more efficient than average and the best-available commercial technology is typically 40%-60% more efficient than average. SEAD efforts focused on other appliance categories would be fully additional to the savings in this specific example.

Global Superior Energy Performance (GSEP) Partnership: LBNL and Oak Ridge National Laboratory (ORNL) analyzed the potential energy savings from the certification component of GSEP, which will drive continuous improvements in the energy efficiency of commercial buildings and industrial facilities. These estimates suggest that, by 2025, if GSEP were adopted by all major economies, it would achieve annual energy savings in the commercial buildings sector of approximately 264 TWh/year (92 Rosenfelds) relative to business-as-usual. In the industrial sector, the annual energy savings would be approximately 4,269 TBtu/year (1,251 TWh/year; 436 Rosenfelds). Combined annual energy savings from GSEP certification programs would thus be approximately 530 Rosenfelds by 2025.[5]

GSEP also includes technical working groups focused on promoting innovative technologies, such as cool roofs and combined heat and power (CHP). By increasing the planet's albedo, cool roofs have the potential to offset the global warming effect of about 31 Gt of CO_2 emissions[6], comparable to the effect of about 350 mid-size coal power plants operating for 30 years. The IEA CHP/DHC Collaborative estimates that accelerated deployment of CHP and related cogeneration and district heating technologies could reduce CO_2 emissions by about 950 Mt/year by 2030 (about 315 Rosenfelds).[7]

Vehicles

The IEA's 450 Scenario projects reductions in transport energy use of 10% below business-as-usual (330 Mtoe/year, or about 2.3 billion barrels of oil/year) by 2030. These reductions require an average investment of about $200 per barrel of oil conserved. The Global Efficiency Challenge addresses this sector through the Advanced Vehicles Initiative (AVI).

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[3] Results updated from McNeill et al. (2008). Global Potential of Energy Efficiency Standards and Labeling Programs. LBNL-760E.

[4] A. Phadke. Pers. comm., July 2, 2010.

[5] See Appendix for underlying assumptions.

[6] S. Menon, H. Akbari, S. Mahanama, I. Sednev and R. Levinson. 2010. Radiative forcing and temperature response to changes in urban albedos and associated CO_2 offsets. *Environ. Res. Lett.* 5 014005

[7] IEA (2008). *Combined heat and power: Evaluating the benefits of global investment.*

Smart Grid

The International Energy Agency's *Energy Technology Perspectives 2010* estimates that smart grid technology could reduce annual CO_2 emissions by between 0.9 and 2.2 Gt CO_2/year in 2050 – equivalent to about 300 to 730 Rosenfelds. These estimates are based on a model developed by the Electric Power Research Institute that takes into account smart grid enablement of energy savings through continuous commissioning of large buildings, reduced line losses, better peak load management, consumer feedback on energy use, and accelerated deployment of efficiency programs, as well as additional CO_2 savings from better renewables integration and facilitation of plug-in hybrid electric vehicles.[8]

The Global Efficiency Challenge addresses smart grid development and deployment through the International Smart Grid Action Network, which will facilitate tapping this potential.

Clean Energy Supply

Solar and Wind

The IEA 450 Scenario requires cumulative investments beyond business-as-usual in wind and solar energy of about $1.4 trillion for large-scale on-grid generation over the next two decades, as well as an additional $600 billion for decentralized generation. These investments yield electricity production in 2030 of about 3,600 TWh/year (1,200 Rosenfelds). Given these investments, costs for wind generation are expected to fall from 9-12 cents per kWh in 2008 to 7-9.5 cents per kWh in 2030, while costs for large-scale solar generation are expected to fall from 13.5-75.5 cents per kWh in 2008 to 7-30.5 cents per kWh in 2030. The Multilateral Solar and Wind Working Group aims to catalyze investments in this area.

Carbon Capture, Use and Storage

The IEA 450 Scenario requires cumulative investments beyond business-as-usual in CCS energy of about $550 billion over the next two decades. These investments yield electricity production in 2030 of about 1,600 TWh/year (530 Rosenfelds). The Carbon Capture, Use and Storage (CCUS) Action Group aims to catalyze investment in this area.

Clean Energy Access

Off-Grid Appliances

SLED has a five-year goal of facilitating the extension of quality-assured off-grid energy access to at least 10 million low-income individuals in low- and middle-income countries. Displacing 10 million kerosene lamps with solar LED lanterns, the first major category of off-grid appliances on which SLED will focus, would yield lifetime CO_2 reductions of about 7.7 million tons.[9]

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[8] EPRI (Electric Power Research Institute) (2008), *The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid*, No. 1016905, EPRI, Palo Alto, California.
[9] E. Mills (2010). From Carbon to Light, Lumina Project Technical Report #5.

Table 2: Estimated Equipment Efficiency Electricity Savings Potential (Rosenfelds)

Equipment Category	2020	2030
Lighting	200	288
Refrigeration	93	218
Residential	*60*	*158*
Commercial	*33*	*60*
Air Conditioning	34	153
Residential	*6*	*41*
Commercial	*28*	*112*
Televisions	65	133
Standby Power	45	117
Ventilation	11	40
Laundry	18	40
Fans	9	28
Oven	11	24
Office Equipment	3	10
Electric Water Heating	6	97
Electric Space Heating	37	82
Industrial Motor Systems	27	89
Total	560	1,319

Calculated with the LBNL BUENAS model (McNeil et al., 2008). Potential savings are efficiencies levels that are currently available and cost-effective, or likely to be so by the time of program implementation. This level of efficiency is generally considerably less than the maximum technically achievable level.

Appendix: Assumptions Underlying Potential Calculations

SEAD – Overall Potential

McNeil et al. (2008) and Table 2 in this report use the energy efficiency standards & labeling (EES&L) forecasting model BUENAS (Bottom-up Energy Analysis System) to assess the total global impact of "best practice" EES&L policies. They define potential savings as those reductions in consumption that would occur if equipment efficiencies reached levels that are currently available and cost-effective, or likely to become so by the time of program implementation. This level of efficiency is generally considerably less than the maximum technically achievable level.

Their calculation assumes global scope and covers the following end uses:

- *Residential Sector:* Lighting, Refrigeration, Air Conditioning, Washing Machine, Fans, Television, Standby Power, Oven, Water Heating and Space Heating
- *Commercial Sector:* Lighting, Space Cooling, Ventilation, Refrigeration, Water Heating and Space Heating.

The BUENAS model has three components:

1) *An activity forecast module* that estimate current end-use demand, and to predict how much growth will occur in the next decades by end-use, and by country or region;
2) *A unit energy savings potential module* that considers relative improvements at the end-use level based upon bottom-up expert judgments about what is feasible in a given time and about cost-effectiveness; and
3) *A stock accounting module* that tracks product flows and retirements, as well as energy consumption of stock.

SEAD – Targeted Super-efficiency Promotion

Phadke (pers. comm.) provides first-order estimates of the potential energy savings from internationally coordinated programs that promote super-efficiency in televisions, lighting, refrigerators, air conditioning and standby power. These estimates employ simplifying assumptions that will be revised significantly as the programs are more fully developed.

Baseline end-use demand projections are based on methodology and data described in McNeil et al (2008). These projections take into account the effect some of the business as usual improvements in energy efficiency expected in the future as well as the effect of proposed standards. For TVs, they have been modified to take into account some more rapid improvements in energy efficiency than assumed by McNeil et al (2008); in particular, they assume that all TVs will meet Energy Star 4.0 levels by 2012.

The calculations assume that the programs target products that are 33% more efficient than products typically sold in the market. By comparison, in the U.S., Energy Star products are typically 20%-30% more efficient than average and the best-available commercial technology is typically 40%-60% more efficient than average.

The calculations further that SEAD coordinated incentive programs target only new purchases and that the turnover times for televisions, lighting, refrigerators, air conditioning and standby power are, respectively, 10 years, 10 years, 20 years, 15 years, and 10 years. They also assume that, averaged over the period starting in 2011 and ending either in 2020 or 2030, the programs achieve a penetration rate of 50%.

GSEP Certification

LBNL conducted an analysis of commercial buildings, while ORNL conducted an analysis of industrial facilities; the approaches used were similar. The major inputs affecting the calculated energy savings are assumptions about program penetration and energy savings in each of the major economies. Penetration describes participation in GSEP, measured as the share of total energy consumption in either the commercial or industrial sector that comes from participating facilities on a country-by-country basis; energy savings describes the reduction in energy consumption relative to business-as-usual for the participating facilities. For both commercial buildings and industrial facilities, GSEP participation is assumed to start in 2015 for all countries except the U.S. (which is assumed to start in 2011 since the U.S. is already piloting a similar initiative in the industrial sector).

Commercial Buildings Assumptions: By 2025, penetration will be 30% in the U.S., 13% in other OECD countries (Australia, Canada, European Union, Korea, Japan, and Mexico), and an average of 23% in targeted non-OECD countries (Brazil, China, Indonesia, India, South Africa and Russia; penetration among those countries will vary). We anticipate that many other countries will also participate, but those potential savings are not reflected here. The assumed penetration in targeted non-OECD countries is relatively high because new facilities are more likely to adopt novel energy management systems, particularly in emerging economies facing chronic energy shortages. Moreover, emerging economies' governments have been focusing increasing attention on energy efficiency, as evidenced by China's efficiency efforts in its five-year plan and India's recently-approved National Mission for Enhanced Efficiency. The annual energy savings in participating facilities is assumed to be 5% for the first 3 years of the program and 3% thereafter.

Industrial Facilities Assumptions: By 2025, penetration will be 30% in the U.S., 13% in other OECD countries, and an average of 28% in targeted non-OECD countries. We anticipate that many other countries will also participate, but those potential savings are not reflected here. The annual energy savings in participating facilities is assumed to be 2.5% for the first 3 years of the program and then 2% thereafter, with the faster rate initially reflecting the fact that there is "low-hanging fruit" that will be relatively easy to capture upfront. Even after these improvements, GSEP will drive annual increases in energy savings through its focus on continuous improvements as a requirement to maintain certification.

<u>GSEP Technical Working Groups</u>

Cool roofs: Menon et al. (2010) estimate the global emitted CO_2 offset afforded by using the NASA GEOS-5 Atmospheric General Circulation Model to calculate the effect of an increase in the albedo of urban areas by 0.1 (from a current range of 0.09-0.27 and a current mean of about 0.14). They scaled this result to estimate the cool roofs potential by assuming that cool roofs increase roof albedo by 0.25 and that roof areas constitute 25% of urban areas ($\sim 3.8 \times 10^{11}$ m^2).

Combined Heat and Power: CHP deployment in IEA's "Accelerated CHP Scenario" was calculated based on each country's heating and cooling demand in the industrial, commercial and residential sectors. Taking into account different national circumstances, IEA estimated the proportions of current and future heating / cooling demand in each country that could be reasonably served by CHP, assuming a pro-CHP policy regime corresponding to the rates of CHP development similar to those seen over the last three decadesi n Denmark, the Netherlands and Finland. The energy savings benefits were then estimated using a model developed by the World Alliance for Decentralized Energy, which incorporates the system-level heat benefits of CHP, as well as the costs of building electricity networks to connect centralized and CHP power plants.

<u>SLED</u>

Current world sales of small off-grid lighting systems are estimated at 500,000 units per year with an annual growth rate of approximately 20%. SLED's activities, which include development of a quality seal, provision of growth capital and trade financing, and implementation of consumer education campaigns, are expected to lead to improved quality and increased sales growth. The target of 10 million people reached assumes widespread adoption of the quality seal and an increase in annual sales growth to 50%.

CO_2 calculations are based on an estimate of 319 L of kerosene (0.77 tons of CO_2) displaced over the ten year lifetime of each product (Mills, 2010).