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Energy efficiency as an inexhaustible energy resource with perspectives from the U.S. and Turkey‡

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SUMMARY

We are familiar with fossil fuels as the primary energy resources, but the time has come to firmly establish energy efficiency as an important energy resource to be considered in future energy investment decisions. Energy efficiency is already being touted as the '6. Fuel' after coal, oil, natural gas, nuclear energy, and renewable energy (hydroelectric, wind, solar, geothermal, etc). Energy efficiency is also the cheapest resource: The cost of electricity obtained from energy efficiency is usually between 1 and 3 cents (U.S.) per kWh. Further, energy efficiency is local and labor intensive with significant benefits to the environment by displacing pollution.

The impact and importance of energy efficiency is well-established in developed countries, but this is not yet the case in developing nations. Therefore, there is a need to raise awareness about energy efficiency, and this is best done by publicizing the successful applications and their impacts. As a striking example, if the refrigerators in the U.S. were to consume electric power at the 1974 levels, the U.S. would need about 30 000 MW of additional installed power to meet this extra demand, which is equivalent to the peak power of Turkey—a country of 70 million. This means 60 coal plants with an average rated power of 500 MW and a construction cost of about $60 billion. Also, the conservation measures that were put in place in 1970s and 1980s in the U.S. became sufficient to meet most power needs of the growing economy, and consequently, a total of 97 nuclear power plants at different stages of construction with a total capacity of 107 000 MW were cancelled. Energy efficiency continues to be recognized as a major energy resource. As detailed in its energy policy report Vision 2025, the U.S. plans to meet at least 50% of the expected future load growth by energy efficiency. The developing nations should take notice of these developments and give energy efficiency the highest priority in energy investment decisions to meet growing demand.

KEY WORDS

energy; energy efficiency; energy source; energy conservation; impact of energy efficiency

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1. INTRODUCTION

To meet its energy needs, the world community currently depends heavily on fossil fuels that are non-renewable and unfriendly to the environment. In 2007, fossil fuels accounted for 81% (26% coal+34% oil+ 21% natural gas) of the total energy use and 68% of total electricity generation in the world. Renewable energy (including hydroelectric power), which is environment friendly and can be harvested indefinitely, was responsible for 13% of the total energy use and 18% of electricity generation globally. Nuclear power supplied the remaining 6% of the total energy use and 14% of electricity generation. The total worldly electricity generation rose from 6.1 trillion kWh in 1973 to 19.8 trillion kWh in 2007, and the total annual CO_2 production during the same period has increased from 15.6 billion ton to 29 billion ton [1,2]. But this fossil-fuel-based economy is not sustainable since the estimated life of known reserves is roughly 250 years for coal, 60 years for oil, and 80 years for natural gas.

Fossil fuels have been powering the industrial development and the amenities of modern life since the 1700s, but this has not been without the undesirable side effects. The conversion of fossil fuels to thermal energy via combustion affects the environment and the air we breathe in many ways, and thus an analysis of energy systems is not complete without considering its impact on the environment and health. Pollutants emitted during the combustion of fossil fuels are responsible for smog, acid rain, and global climate change. The environmental pollution has reached such high levels that it became a serious threat to vegetation, wild life, and human health. Air pollution has been the cause of numerous health problems, including asthma and cancer. Therefore, the switch to non-fossil energy sources is inevitable, and salvaging the energy that is currently being wasted stands as the greatest resource that can be tapped on to meet the growing energy demand of the world.

When energy sources are discussed, the first things that come to mind are coal, oil, and natural gas, uranium mines that power nuclear plants, and the renewable energy sources such as the sun, wind, geothermal, and biomass. However, the largest energy resource that we can readily tap on is a virtual energy source that was discovered in 1973 after the oil embargo. This resource is everywhere, including our homes, and many economy giants like the U.S. are meeting half of their new energy demand to power economic growth from this resource. The amount of energy extracted from this resource is comparable to the energy obtained from coal, oil, natural gas, nuclear, and renewable energy. What is more, this resource does not occupy any space, it does not face depletion, and it benefits the environment instead of harming it. The name of this resource is energy efficiency.

It is unfortunate that developing countries are investing their limited financial resources on building new power plants and extracting or importing more oil and natural gas to meet their growing energy demand rather than investing in energy efficiency as their first priority. The primary aim of this paper is to raise awareness that investing in energy efficiency provides the highest and fastest returns on investment, and that energy efficiency is not something that can be done only if there is some funding available. Also, it is not something that can be left to individuals and companies. As the experience from the modern world indicates, a strong commitment by the governments and providing leadership is essential in raising public awareness and in initiating change toward energy efficient technologies and practices.

The 1973 oil embargo made life miserable in the Western world, and displeasure toward Arab nations was the common feeling for causing this misery. But looking back, Western countries view the oil embargo as a blessing since it awakened people from the false illusion that the low-cost energy will be at their disposal forever. Therefore, the wake-up call in 1973 has been a turning point for the way energy was perceived, and it marked the beginning for the serious all-out energy conservation efforts. At the end, the Western world has devised the necessary mechanisms to achieve the highest level of thermal comfort with the lowest level of energy expenditure. This is done by incorporating energy efficiency measures in all aspects of life.

As a developing country, Turkey has plenty of energy resources and yet imports 74% of the energy it consumes. It is heavily dependent on imported energy, and this dependence is deepening because of its fast economic growth and the proportionate growth in its energy demand. Despite its vast renewable energy resources, in 2007 only 9% of the energy it consumed came from the renewables, including hydroelectric. In 2007, it imported 97% of the natural gas, 93% of the oil, and 20% of the coal it consumed. In 2008, 48% of the 198 billion kWh of total electric production of Turkey came from natural gas power plants. The share of hydroelectric power production has dropped from 40% in 1990 to 17% in 2008 while wind power accounted for only 0.4% in 2008. Turkey's electricity demand is projected to increase at an average annual rate of about 6% during the next decade, reaching 460 billion kWh 2020. The installed power capacity is also projected to increase from its 2008 value of 41 700 MW to about 88 000 MW in 2020. The high degree of dependence on imported energy is a risk factor on energy security, and it adversely affects the trade imbalance. Turkey has turned its attention to renewable energy and energy efficiency in recent years, but the activity level is far from being adequate.

2. ENERGY INTENSITY: A MEASURE OF ENERGY EFFICIENCY

Earning money is no doubt important for a comfortable living, but spending the earned money wisely and avoiding waste is no less important. Likewise, extracting energy from a resource is important, but using this energy in the most efficient way and avoiding waste is just as important.

Energy efficiency is to reduce energy use to the minimum level, but to do so without reducing the standard of living, the production quality, and the profitability. Energy efficiency is an expression for the most effective use of the energy resources, and it results in energy conservation. There is close connection between efficiency and conservation, and these two terms are often used interchangeably. Energy conservation is usually associated with the measures taken to reduce energy use at the final point of consumption, such as the use of electricity in a house for lighting. Energy efficiency, on the other hand, is associated with the most efficient and thus least wasteful use of energy at all stages from production to end use. Therefore,

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energy efficiency is a broader term that includes energy conservation. The second law of thermodynamics is closely associated with energy efficiency: A second-law efficiency of 100% corresponds to zero waste and thus the upper limit for energy efficiency [3].

The concepts of energy conservation and renewable energy appear to be independent of each other, but they are closely associated. If the energy of wind is not captured by a wind turbine or if the solar energy incident at a location is not collected by solar collectors or PV cells and is converted into a usable form right away, it will go to waste and simply contribute to global warming. Burning natural gas for energy that can be obtained from the wind or the sun is simply the unnecessary use or waste of natural gas. Therefore, the increased utilization of renewable energy is one of the most effective measures of energy conservation.

A common measure of energy efficiency for an economy is *energy intensity*, which is the amount of energy used to produce a dollar's worth of gross domestic product (GDP). The energy intensity of Turkey, for example, is twice that of the OECD average. That is, Turkey uses twice as much energy to produce a dollar's worth of goods and services as the OECD countries do. Further, Turkey consumes more than twice the energy the European Union countries use for space heating per unit floor area under comparable climatic conditions. This high level of energy waste raises concerns, but it also points to the great opportunities that exist in energy efficiency: Turkey can reduce its energy consumption by half without reducing its standard of living by simply incorporating measures of energy efficiency in all aspects of life. In other words, Turkey can meet its growing energy needs demanded by its growing economy until its GDP is doubled by implementing energy efficiency measures alone without tapping on any additional energy resources. That is, the only kind of power plant Turkey (and countries in similar situation) needs to power its economic growth is the 'conservation plant' that has no chimneys and emits no pollutants instead of the usual coal, oil, or natural gas power plants that pollute the air, cause global climate change, and jeopardize energy security. The most effective way to combat rising energy costs, greenhouse gas emissions, and foreign dependence on energy is to increase energy efficiency and thus to reduce energy intensity. In nations with a high level of energy awareness such as the U.S., energy intensity continues to decline and thus energy efficiency continues to rise. The energy efficient technologies developed since early 1970s and the conservation measures that are put to use played a major role in this increase in energy efficiency. The energy use per dollar of GDP in the U.S. has dropped by 40% from 1980 to 2005, as shown in Figure 1, and this drop is projected to reach 60% in 2030.

Energy efficiency covers a large area from insulation to energy-efficient lighting and from energy-efficient appliances to high-efficiency electric motors. The energy-efficient compact fluorescent lamps (CFL), for example, consume one-third to one-fifth of the electricity that incandescent lamps consume for the same light output. So it is no surprise that the use of incandescent lamps is being banned or restricted in Australia, European Union, and the U.S., and the tariffs applied to energy efficient lamps are being lifted. Further, the energy consumption of fluorescent tube fixtures commonly used in public, commercial, and industrial buildings can be reduced by up to 30% by simply replacing the magnetic ballasts with their electronic counterparts. This replacement has the added benefit of eliminating the irritating buzzing sound, the flickering of light, and the reactive power loss by raising the power factor from 0.60 to 0.99. Electronic

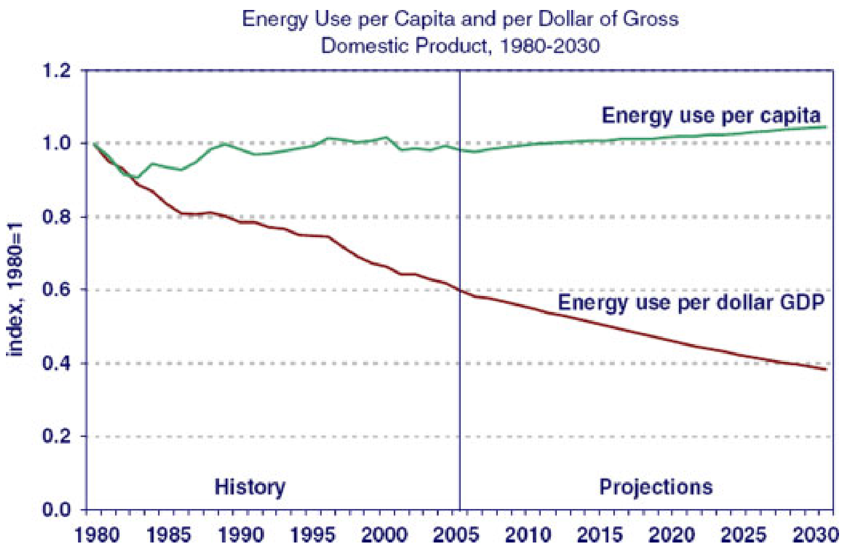

Figure 1. The decline in the energy intensity of the U.S. economy [1].

ballasts operate at lower and thus safer temperatures with a longer life because of their higher efficiency and thus lower rate of heat production. They fit into existing fixtures, are economical, and easy to install. Additional savings can be realized by replacing the old type fluorescent tubes by the newer more energy efficient ones that provide the same amount of lighting (34 W instead of 40 W, for example).

Energy efficiency efforts also had a major impact in the transportation sector. Cars in the U.S. in 2001 used roughly 60% of the gasoline they did in 1972 per mile driven, due in part to new technologies such as better engine design and controls, improved transmission, weight reduction, and improved aerodynamics. The energy efficiency of cars continues to improve further by using advanced light-weight materials and hybrid technology. Considering that transportation accounts for 27% of total U.S. energy consumption and cars and light trucks comprise over 75% of it, even a small increase in energy efficiency of vehicles can have a major impact on the human health and the environment [4]. Therefore, governments continue to offer generous incentives toward the purchase of fuel-efficient vehicles and use legislation to discourage the production of fuel-inefficienct vehicles.

It is unfortunate that many nations in the world are not even aware of the power of conservation, and they spend their limited resources to build new power plants instead of investing in energy efficiency. Obviously what the world needs the most are green 'conservation' plants, which also benefit the human health and the environment.

3. THE POWER OF ENERGY EFFICIENCY

Two examples from the U.S. clearly demonstrate the power of energy efficiency. The first one deals with household refrigerators and the second one with nuclear power plants.

3.1. The case of energy efficient refrigerators

The energy efficiency of refrigerators and freezers has increased greatly over the last 30 years, and the trend for higher energy efficiency in all appliances continues. In 1974, a typical refrigerator in the U.S. consumed 1800 kWh of electricity per year. But owing to the efficiency enhancements in motor and compressor systems, more effective insulation, and improved control systems, the average annual electricity consumption has declined by 75% to 450 kWh. That is, an average refrigerator in the U.S. today consumes only one-fourth of the electricity it consumed in 1974, and thus saves 1350 kWh of electricity each year. The total number of refrigerators in the U.S. is 140 million, and the national average price of electricity is 10.4 cents [5]. Then it follows that the energy efficiency in the refrigerators alone saves the U.S. 189 billion kWh of electricity per year (which is equal to the total annual electricity consumption of Turkey—a country of 70 million), and nearly $20 billion stays in the pockets of U.S. consumers rather than going toward paying electric bills. Further, considering that an average of 0.713 kg of CO_2 is emitted per kWh of electricity generated in the U.S., the 189 billion kWh of electricity saved offsets the emission of 135 million ton of CO_2 (the actual amount will be larger since a greater amount of electricity needs to be generated to make up for the transmission losses). Therefore, the conserved energy also makes a significant contribution to the efforts to avoid global warming.

If the refrigerators in the U.S. were to continue to consume electric power at the 1974 levels, the U.S. would need about 30 000 MW of additional installed power to meet this extra demand. This means 30 nuclear power plants with an average rated power of 1000 MW or 60 coal plants with an average rated power of 500 MW. Assuming an average construction cost of \$2 million MW^{-1} for coal plants, the construction cost of these power plants to meet the additional demand due to refrigerator inefficiency would be $60 billion. At \$0.065 kWh^{-1} for fuel and other operational expenses, it would cost $12 billion a year to operate these additional power plants. Therefore, the implementation cost of energy efficiency measures should be compared with all these costs that are offset. It is interesting that the 30 000 MW also corresponds to Turkey's peak power, and thus we can say that if the efficiency level of the U.S. refrigerators remained at the 1974 levels, they would now be consuming extra electric power that would be sufficient to meet the electricity needs of a country with a population of 70 million.

3.2. The case of cancelled nuclear power projects in the U.S.

Another area where conservation measures have had striking effects is the cancelled nuclear power plant projects in the U.S. As of the end of 2008, there are 436 nuclear power plants in the world with total rated power of 370 000 MW, producing 14% of total electricity consumed in the world. 104 of these with a rated power of 98 000 MW are in the U.S., supplying 19% of the electricity it consumes.

Before discovering conservation, the U.S. was planning to power economic growth mostly with nuclear energy, and started the construction of dozens of nuclear power plants in the 1970s. But something unexpected has happened: the conservation measures turned out to be sufficient to meet the power needs of the growing economy. Consequently, a total of 97 nuclear power plants at different stages of construction with a total capacity of 107 000 MW were cancelled,

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and billions of dollars invested was wasted [6]. About 90% of these cancellations have occurred between 1974 and 1984 (the rest were cancelled between 1985 and 1995) and no new nuclear plants have been built in the U.S. since 1979. This shows the effectiveness of conservation measures, and teaches an important lesson that energy efficiency should be given the highest priority in energy planning [6].

3.3. Impact of energy efficiency in the U.S.

The best way to minimize the use of a natural resource is not to use it at all—that is, to conserve it. But this should be done without lowering the quality of life. This is the approach taken in the U.S. in 1970s after the oil embargo, and conservation measures were given a high priority. The results of these efforts have been impressive: Between 1975 and 1985, the total energy use has remained constant while economic growth continued, as shown in Figure 2. That is, the energy needed to power the economic growth is supplied by conservation. Between 1973 and 2000, the U.S. economy has grown 126% but the increase in total energy usage has remained at 30%—about one-fifth of the rate of economic growth. Also, between 1990 and 2000, the industrial output has increased 41%, while the use of electric energy in industrial facilities has increased only by 11% [4].

If the U.S. had not turned to conservation and continued its energy use at the energy intensity level of 1970, its energy consumption would have been 70% or 70 Quad more in 2000, and the U.S. would be paying about $2 billion more every day for energy. Today the U.S. is paying about 700 billion dollars less for energy every year, and it owes this to the conservation measures it started zealously in 1970s. Therefore, the past investments in energy efficiency have paid a very high return while providing economic stimulus and environmental and thus health benefits. The U.S. example reaffirms that the biggest energy resource is energy efficiency, and this is a domestic, environment friendly, and inexhaustible resource [4].

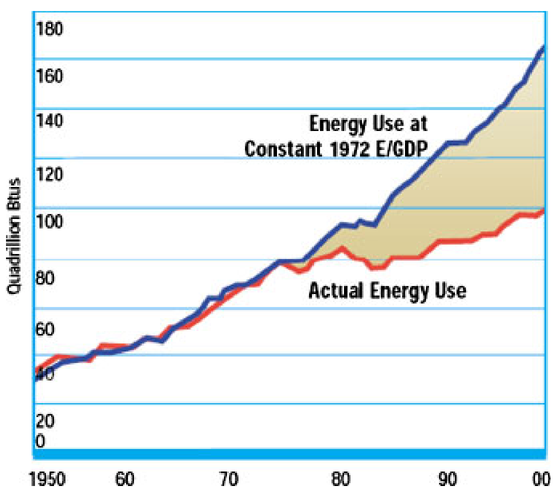

Figure 2. Total energy usage in the U.S. [4].

4. IMPACT OF BASIC ENERGY EFFICIENCY MEASURES

4.1. Insulation: the first step in energy efficiency

When the topic is energy conservation, the first thing that comes to mind is usually insulation. For decades, insulation has been one of the cornerstones of energy conservation project, and it plays an important role in sustainable economy. The cumulative insulation products installed in U.S. buildings save consumers about 12 Quad a year, or about 42% of the energy that would have been consumed with no insulation in place. Insulation also benefits the environment and human health. Insulation installed in U.S. buildings prevents the emission of over 780 million ton of carbon dioxide annually. In the U.S. alone, $5.9 billion could be saved annually in healthcare and economic costs linked to air pollution simply by improving insulation, with the additional benefit of the improved quality of life [7]. In a 2001 report, the conservation provided by the current level of insulation in residential, commercial, and industrial building is stated to be 23.5 Quad of energy (1 Quad of energy is equivalent to 4 billion barrel of oil, which for a unit price of $58 barrel^{-1}, is worth $10 billion), $177 billion, and the elimination of the 366 million ton of carbon (or 1340 million ton of carbon dioxide) emission [8]. Also, the energy use in U.S. Government buildings per unit floor area is reduced 20% between 1985 and 2000.

Insulation projects often pay for their cost within a few months from the cost of the energy they save. During an energy audit of a manufacturing facility, for example, it is observed that the outer surface temperature of a furnace was 90°C, and calculations showed that the cost of heat loss is $7400 per year. The recommendation was to insulate the outer surfaces with 5 cm thick insulation, at a total cost of $1400, which dropped the cost of heat loss to $1700 per year. That is, a one-time investment of $1400 has resulted in $5700 worth of energy conservation per year, and the insulation paid for itself within 3 months. Viewing the energy efficiency as a resource, it seems like a manufacturer taps into this resource by paying a one-time fee of $1400 and starts to rip off annual benefits of $5700 while another manufacturer taps into natural gas line and continues to pay $7400 every year. This gives the first manufacturer the competitive edge and increases its profitability. Such energy efficiency practices also benefit the environment.

In contrast, over 80% of the buildings in Turkey have little or no insulation and the savings if these buildings are properly insulated and thus heat losses are largely eliminated is estimated to be \$7 billion per year. That is, if the buildings are properly insulated, \$7 billion will stay in the pockets of consumers rather than going up in the smoke through the chimneys and polluting the environment. To make this a reality, the public awareness must be raised and all concerned must be educated. The governments' leadership and the incorporation of financial incentives are important, but the trade groups, engineering societies, and even the universities must play an active role in this undertaking. The new building code that took effect in December 2009 will insure that the new buildings are properly insulated. But the need to develop the necessary mechanisms to bring the existing building stock to code remains. Such moves will also bring the country closer to achieving energy independence and security and to meet the targets for greenhouse gas emissions.

4.2. Energy-efficient lighting

In the U.S., 22% of the electricity is used for lighting, which amounted to 880 billion kWh in 2007. Although there are large variations with wattage and manufacturer, incandescent light bulbs produce less than 18 $\mathrm{lm\,W^{-1}}$) and less than 6% of the electric energy they consume is converted to light. They also have a short operation life of about 1000 h. In halogen lamps, these upper limits can be doubled. These values are likely to improve since incandescent lamps produced in the U.S. in 2012 must be 25% more efficient relative to those produced in 2007 or face extinction, in accordance with the Energy Independence and Security Act of 2007. Incandescent lamps are also being phased out or banned in many other countries.

Fluorescent lamps (compact and tubes) produce up to 105 $\mathrm{lm\,W^{-1}}$ and have electric-to-light conversion efficiencies of up to 35%, with an operation life of about 10 000 h. High-intensity discharge lights have comparable performance to fluorescent lamps. Low-pressure sodium lights produce up to 200 $\mathrm{lm\,W^{-1}}$, but their use is limited because of their characteristic yellow tones and thus poor color rendering index. Improvements in the solid-state technology in recent years resulted in the development of LED lamps, which is seen as the future of lighting. LED lighting devices have a potential to produce 400 $\mathrm{lm\,W^{-1}}$ of white light. The 2025 goal of the U.S. is to achieve an efficacy of 200 $\mathrm{lm\,W^{-1}}$, which corresponds to electric-to-light conversion efficiency of 50%, and to reduce the energy consumption for lighting by half. This level of saving is equivalent to shutting down 52 of the 104 nuclear power plants in the U.S. or to avoid the construction of that many new nuclear or fossil fuel power plants. This will also result in 11% reduction in the greenhouse gas emissions associated with electric power production, and an annual savings of \$30 billion by consumers.

At times of energy crises, replacing inefficient incandescent light bulbs by energy-efficient fluorescent ones is the first measure that comes to mind since it produces quick results at low cost. In 2001, for example, California distributed 8 million CFLs to low income families to lessen the effect of the electricity crises. Brazil also used the same approach in 2001. Turkey mandated in 2008 all government buildings to switch to energy efficient lighting.

4.3. Energy efficiency in electric motors

About half of all electricity produced in Turkey and two-thirds of the electricity used in industry is consumed by electric motors. This shows the importance of using high-efficiency motors in industry to reduce energy cost. The purchasing cost of a typical new motor is less than 2% of the total cost of that motor. The life-long energy cost of a motor can constitute 98% of the total cost. That is, a typical motor will cost over 50 times its purchasing price in energy it consumes during its average life of 20 years. In other words, the cost of energy a typical electric motor consumes in a few months may equal the purchase price of that motor. On average, a motor consumes its purchase-price worth of energy within 2 months. The total energy cost of a motor with a price tag of \$5000 can exceed \$1 million during its life time.

Many production managers are not aware of the seriousness of the matter. They often prefer the standard efficiency motor over the high-efficiency one because of the price differential (usually between 10% and 25%), but later they pay several times this difference in energy costs. They also rewind the burned-out motors repeatedly to avoid the cost of new motors. But rewinding causes the motor efficiency to drop even further, and the money saved by repairing an old motor quickly disappear because of the increased energy costs. A new high-efficiency motor purchased to replace the old one, on the other hand, will pay its cost differential in a short time from the energy it saves, and will continue to conserve energy and money during the rest of its operation life.

As an example: The efficiency of a 20 hp standard motor is about 88%. But the efficiency of high-efficiency motor with the same rated power output is 91%, and it even rises to 93% in the case of premium efficiency motors. Purchasing a 93.0% efficient premium efficiency 20 hp motor that operates 6000 h a year with an average load factor of 75% instead of an 88.3% efficient standard motor will result in annual energy savings of 4102 kWh. Assuming a CO_2 emission of 0.75 $\mathrm{kg\,kWh^{-1}}$, the premium efficiency will prevent the release of nearly 3 ton of greenhouse gases into the atmosphere. As an added benefit, high-efficiency motors reduce the operation costs because of their higher reliability (and thus

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fewer breakdowns and less production loss due to fewer shutdowns) and lower maintenance costs.

By switching to high-efficiency motors, a savings of about 4% from energy consumption is possible. But when the load is variable as in the case of fans, pumps, compressors, and conveyors, it is possible to reduce the energy consumption by 50% and in some cases by 70% by equipping the motors with variable speed drives (VSD). This way, the competitiveness and profitability of industrial facilities can be improved by reducing the cost of energy significantly. In Turkey, a saving of 25% in pump and fan systems will result in annual energy and cost savings of 9 billion kWh and about $1 billion, respectively. Municipal pumping stations, well-water pumping systems in farms, an even residences that meet water needs from their own wells can benefit from the savings provided by VSD's. The cost of VSD may be several times that of the motor it is mounted on. But in many cases the VSDs pay for themselves during the first year from the cost of the energy they save.

As an example, equipping a 90 kW motor in a pumping station in Kavacik, Istanbul with a VSD has resulted in a drop in the average daily electric consumption from 1370 kWh to 690 kWh—a drop of 49.6%. This corresponds to annual energy and cost savings of 248 000 kWh and $30 000, respectively. The simple pay back period for this VSD system was less than 1 year. This VSD application has also benefited the environment by avoiding the emission of about 16 ton of CO_2 gases into the atmosphere.

4.4. Replacing old appliances by new energy-efficient ones

In Turkey, about 7% of electricity is consumed by household refrigerators. Homeowners have paid about $1.4 billion in 2007 for the 11 billion kWh of electricity that the refrigerators have consumed. The refrigerators are classified as A++, A+, A, B, C, D, and E based on their energy efficiency. The annual electricity consumptions of the refrigerators in these categories are 274, 383, 507, 639, 832, 916, and 1149 kWh, respectively. That is, a class E refrigerator consumes twice as much electricity as a class A refrigerator of the same size, and nearly three times as much as a class A+ refrigerator. Therefore, encouraging consumers to purchase high-energy efficiency refrigerators and other household appliances by offering incentives to consumers and/or manufacturers has long been part of energy efficiency measures in the U.S. and EU countries. In the U.S., for example, consumers are offered rebates between $75 and $175 toward the purchase of refrigerators, depending on the level of energy efficiency. Manufacturers of high-energy efficiency models are also offered incentives to partially offset the extra cost associated with the development and production of energy efficient appliances. In EU countries, incentives up to 200 Euros are given for high-efficiency refrigerators.

Turkey currently does not have an incentive program for high-efficiency appliances, but is considering one to encourage consumers to trade in their old refrigerators for new ones with a minimum efficiency level of class A. Considering the world experience and the price differential between different models, a $200 incentive appear to be sufficient to motivate people to replace their old refrigerators with a new one.

The market penetration of refrigerators in Turkey is 100%, and considering the number of households and the refrigerator sales during last 10 years, it is estimated that there are about 4 million refrigerators that are older than 10 years. Their energy efficiency level is estimated to correspond to class D refrigerators. The total cost of incentives to replace these old refrigerators by class A ones is $800 million. But the new energy-efficient refrigerators will save about 1.6 billion kWh of electricity per year which is worth about $200 million. It will also eliminate the need to construct a new power plant with a rated power of 430 MW whose construction cost will be about $550 million for the case of natural gas power plant. That is, the $800 million projected incentive cost will mostly be spent to build new power plants if not used for incentives. Further, the cost of incentive will be paid back by the cost of energy saved within 4 years. Offering incentives to move consumers to higher-efficiency appliances will look even more attractive if the benefits to the environment are also quantified.

5. A SAMPLE ACTION PLAN FOR ENERGY EFFICIENCY: U.S. VISION 2025

In the U.S., an action plan for energy efficiency is prepared in 2007 through the leadership of over 60 diverse leading organizations under the facilitation of the U.S. Department of Energy (DOE) and the Environmental Protection Agency (EPA), and the plan provides a road map that can be adopted by any country or organization to implement energy efficiency measures in a systematic manner [9]. The plan details the role that energy efficiency can and should play in supplying the future energy needs, and it addresses the challenges of rising energy costs, energy security and independence, pollution, and global climate change. The overall goal of the plan is to achieve all cost-effective energy efficiency by 2025 by improving energy efficiency in homes, businesses, schools, governments, and industries.

The plan clearly establishes energy efficiency as an energy resource, and projects that this resource can meet 50% or more of the expected load growth over the given time frame. In other words, energy efficiency alone can meet a greater fraction of the new energy demand than all the fossil, nuclear, and renewable energies combined. This is not a new concept for the U.S.: Over the past 35 years, energy efficiency has been the greatest domestic source of energy. The annual savings resulting from the lower energy bills is estimated to reach \$100 billion in 2025, and the net savings are projected to exceed \$500 billion, with reductions in greenhouse gas emissions on the order of 500 million metric ton of CO_2 annually, equivalent to 90 million cars off the road. By replacing existing generation options to meet the load growth, energy efficiency will eliminate the need to construct 100 500 MW of power plants over the next 20 years.

The primary reasons for this *Action Plan for Energy Efficiency* are stated as follows: Energy efficiency is a large, untapped, low-cost energy resource; energy efficiency improves energy security; energy efficiency mitigates risk of future carbon policy; and higher prices do not remove the barriers that impede investment in cost-effective energy efficiency. The primary goals of the plan are stated as establishing cost-effective energy efficiency as a high-priority resource, establishing cost-effectiveness tests, establishing effective energy efficiency delivery mechanisms, aligning customer pricing and incentives to encourage investment in energy efficiency, implementing state of the art efficiency information sharing and delivery systems, and implementing advanced technologies.

The plan's recommendations include to recognize energy efficiency as a high-priority energy resource, to make a strong, long-term commitment to implement cost-effective energy efficiency as a resource, to broadly communicate the benefits of the opportunities for energy efficiency, and to provide sufficient, timely, and stable program funding to deliver energy efficiency where cost-effective. So it is no surprice that the U.S. 2009 Economic Stimulas Plan included \$13 billion to improve the energy efficiency of government buildings and to minimize the energy losses of 1 million homes. Also in 2009 California Public Utilities Commission approved a 3-year \$3.1 billion energy efficiency budget. The California program aims at reducing the energy consumption of up to 130 000 homes by 20%, establish zero net energy homes and commercial buildings, make public buildings more energy efficient, and providing education/training. The Europian Union (EU) also established a goal to improve energy efficiency by 20% by the year 2020.

6. CONCLUSION

The conclusion that can be drawn from all past experiences and the above arguments is that countries like Turkey which have not played an active role in energy efficiency arena because of insufficient funds should reconsider their position. They should make energy efficiency the highest priority item in their energy policy, and budget serious funds to make energy efficiency a reality. The U.S. has set a good example in planning to meet at least half of the increase in energy demand by efficiency measures instead of building new power plants and tapping on new energy resources. The U.S. even sees the labor-intensive energy efficiency activities as an opportunity to ease the strain caused by the economic crises. Such measures should work much better in countries like Turkey with a high level of energy waste since there is so much energy that can be saved by incorporating energy efficiency measures. Therefore, energy efficiency should be made a high-priority state policy with serious funds earmarked for it. This will have the added benefit of reversing the economic slowdown and revitalizing the economy. The future of a country whose energy intensity is twice that of OECD countries is in energy efficiency. The primary goal of energy policies of countries with widespread energy inefficiency must be 'zero waste', and an all-out war must be staged to achieve that goal.

The first step in this undertaking is to recognize energy efficiency as a high-priority energy resource. This way, providing continued funding for energy efficiency at sufficient levels can be justified. Public awareness must be raised through well-planned campaigns, and the public should be made aware of the opportunities. Low or zero interest credits with long pay back periods as well as cost sharing must be made available for major energy efficiency projects. Also, most energy efficiency activities with sufficient incentives built into the programs should be managed locally, and local utilities and municipalities should play leading roles.

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