POSSIBLE BREAKTHROUGHS
RETROFITTING IRRIGATION PUMPS

Pumping irrigation is a major source of energy consumption in agriculture. In California, where agriculture uses 80% of the state water supply, 90% of all electricity used on farms is consumed for pumping groundwater for irrigation. Examples from Asia show that the energy consumed in irrigated rice production can be twice as high as in rainfed rice, and groundwater irrigation can be 25% more energy intensive than surface-water irrigation, owing to the force that is required to lift water.[1] In India, government policies have supported groundwater use by supplying cheap diesel or free electricity to farmers to enhance food security. Yet negative externalities associated with over-pumping have often been ignored: irrigation has increased yields but contributed to around 3.7% (58.7 million tonnes CO_2-equivalent) to the country's total greenhouse gas (GHG) emissions in 2000.[2] Groundwater pumping with electricity and diesel accounts for an estimated 16-25 million tonnes of carbon emissions, 4-6 % of India's total.[3] Most of these pumps do not work efficiently. According to Shah,[4] Indian electric irrigation pumps probably operate at 40% efficiency. Studies have shown that electricity savings up to 30% are possible[5] – largely by using improved foot valves, by checking valves and by matching the pump and prime mover better.[6]

[1]Rothausen and Conway 2011, [2]Nelson et al. 2009, [3]Shah 2009, [4]Ibid, [5]Bom 2002, [6]Ibid

Geography

Europe and the U.S.

Policies have been implemented to regulate emissions of diesel engines. For instance in the U.S., the Diesel Emission Reduction Act, executed by the EPA,[7] funds federal or state loan programs to either rebuild diesel-powered engines or install emissions reduction systems. These funds also cover the retrofitting of irrigation pump engine technology. Where possible, diesel pumps have been replaced by electric pumps. However, according to the University of Nebraska, which created the Nebraska Pumping Plant Performance Criteria, (criteria for pump efficiency) more efficient irrigation pumping plants still could save 25-30% of energy on average by properly matching and adjusting the pump and motor to current operating conditions. In Nebraska alone, improvements in pumping plant performance will reduce energy costs by up to US$ 40 million per year.[8]

West Africa

There are several types of motorized pump sets available in West Africa that burn fossil fuels, mostly gasoline or diesel, but sometimes kerosene. Information about the pump sets is fragmented and incomplete and often poorly matched to their applications. The purchase price in West Africa of a Japanese-made gasoline motorized pump set of about 1.5 to 4 kW design output is usually in the range US$ 300-600, and a diesel pump is around US$ 990. Indian-made pump sets tend to cost around US$ 180, while those made in China are considerably cheaper at around US$ 110. These pump sets are often used in applications for which they are seriously overpowered, resulting in unnecessarily high running costs.[9]

[7]US EPA 2007, [8]Kranz 2010, [9]Snell 2004

India

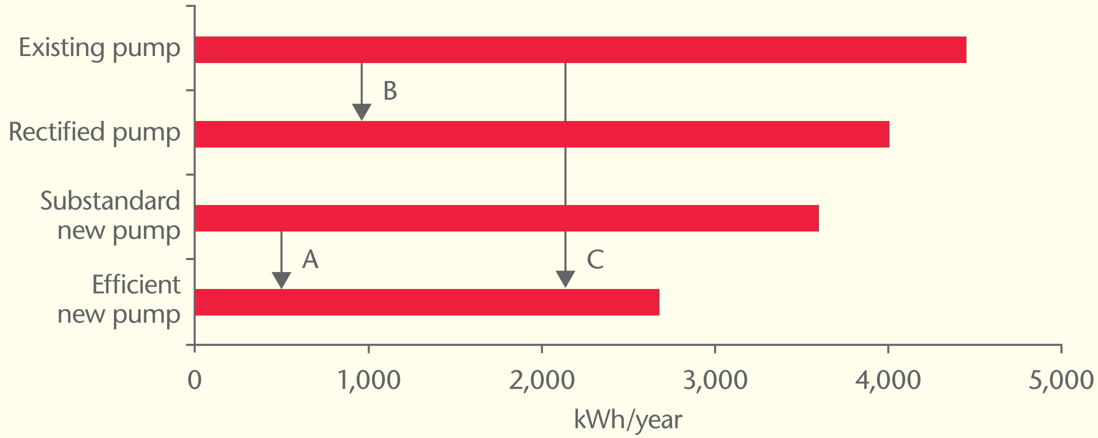
There are millions of diesel pumps operating in South Asia, with India alone accounting for an estimated 6-7 million units.[10] The rising cost of diesel has increased the cost of well irrigation for owners by 32% in south Bihar and 18% in eastern Uttar Pradesh over the 16-year period from 1990-2006.[11] However, there is still discussion about how much this rapid rise in diesel affects farmers. The problem with electric pumps, however, is that power supply to agriculture is highly unreliable, with frequent power cuts and low voltages. The poor quality of supply leads to transformer and motor burnouts. Very often, farmers have to undertake service connection and transformer repair and maintenance work. Thus, even though the tariff is low, the farmer pays a high price for the power by having to replace motors very often and not having power supply when needed.[12] Thus, farmers have little incentive to use electricity efficiently. Nearly 500,000 pumps are added each year to the stock of functioning agricultural pumps, and most of these are not efficient.[13]

China

China is the world's largest emitter of greenhouse gases, and the agricultural sector in China is responsible for 17-20% of annual emissions and 62% of total freshwater use. Groundwater pumping for irrigation alone accounts for roughly 3% of the total emissions from agriculture in China.[14]

Figure 1

Annual electricity consumption (kWh/yr) by selected energy efficiency measures for agriculture water pumping



Note:
A – electricity savings for new pump purchase;
B – electricity savings for pump rectification; C – electricity savings for pump replacement.

Source: Garg et al. 2011

[10]Bom 2002, [11]Kumar 2010, [12]Ramachandra-Murthy and Ramalinga Raji 2009, [13]Sant and Dixit 1996, [14]Wang et al. 2012

Figure 2

Summary of results from 11 diesel-powered pumping plant retrofits

	Before retrofit	After retrofit	Percent improvement
OPE*	14%	23%	64%
Water flow – GPM*	742	1,025	38%
Brake HP Input	80	86	
Engine RPM*	1,734	1,696	
Input HP-hours/acre-foot water pumped	2,237	1,319	-41% (a decrease in energy use)

*RPM = revolutions per minute; OPE = overall pumping plant efficiency, measured in the field and averaged; GPM = water flow from the pump in gallons per minute, measured in the field and averaged.

Source: Canessa et al. 2011

Figure 3

Electric-powered pump retrofit statistics for 41 pumps ranging from 75 to 300 horsepower

1	2	3	4	5	6	7	8	9	10
Condition	OPE (%)	Post-motor OPE (%)	GPM	Total dynamic head (ft)	Input horse-power	kWh/ acre-foot	Annual acre-feet pumped	Annual hours operation	Annual kWh
Before retrofit	38	42	893	274	163	738	400	2,433	295,372
After retrofit	65	72	1,372	316	168	498	400	1,584	199,148
Estimated or measured	Meas	Est	Meas	Meas	Est	Est	Est	Est	Est

Source: Canessa et al. 2006

Energy

- Improved energy efficiency of pumps by 10-15% by i) replacing the existing undersized pipes with the appropriate size and new, rigid, low-friction pipes and
  ii) replacing high-friction foot valves with low-friction and low head foot valves.[15]
- Rectification can decrease electricity consumption by 444 kilowatt-hours (kWh)/year (see figure 1).
- A study in California by Urrestarazu and Burt[16] where 15,000 electric irrigation pumps were tested, showed energy savings of more than 100,000 megawatt-hours (MWh)/year for well pumps, with a per-pump average of 50 MWh/year. For non-well pumps, total potential savings were 16,500 MWh/year and the average per pump was 34 MWh/year. During their life, pumps can lose their initial efficiency through pump wear, changes in groundwater conditions and changes in the irrigation system. Different groupings of pumps were made according to the annual energy consumed and total dynamic head (TDH) and discharge ranges. Averages for all the variables were calculated for each group. Pumps with an overall pumping plant efficiency (OPPE) below the group average are considered to have the potential for improvement. The energy saved by these pumps is estimated as the difference between actual energy consumption and the average of the top 25% of the pump efficiency within that group.
- A study by the Centre for Irrigation Technology at California State University, Fresno[17] testing the efficiency of 11 diesel pumps before and after a retrofit showed 41% energy savings. Retrofitting involved repair or replacement of either the pump bowl or impeller or both (see figure 2).
- Another study undertaken by the Centre for Irrigation Technology at California State University, Fresno[18] tracked 41 electric powered pumps ranging from 75 to 300 horsepower (HP) both before and after a retrofit. Retrofitting resulted in a decrease of 33% in kilowatt-hours (kWh)/acre-foot, a 35% decrease in annual hours of operation and a 33% decrease in kilowatt-hours required per year (see figure 3).

[15]Garg et al. 2011, [16]Urrestarazu and Burt 2012, [17]Canessa 2011, [18]Canessa et al. 2006

Water

- Improved 2.5 horsepower (HP) motor pumps could yield as much water as the traditional 5 HP pumps with half the fuel consumption.[19]

Costs and benefits

- In a study assessing the efficiency of 15,000 electric pumps, savings of US$ 7,400/year/well pump and US$ 5,000/year/non-well pump could be obtained when pump performance was improved to meet the average of the 25% best-performing pumps. Savings depend on the results of the improvement and the price of energy.[20]
- Based on the results of improved overall water-lifting efficiency in Asia, Van't Hof[21] estimated that irrigation pumping costs for rice production in Mali could be cut by 60% per unit area per season. Specific costs included: fuel, interest (10%), repair and maintenance (10% of initial system cost) and depreciation (desk study).
- The technical adaptation of 11 Petter 5 HP/1500 RPM pumps resulted in 45-60% less fuel use for shallow pump sets in India. This was obtained by removing the foot valve or check valve, reducing the engine speed and increasing the cooling water temperature. For deep pump sets, the average fuel efficiency could be improved by 35%. This means a potential 15% savings on high-speed diesel imports on a national level.[22]
- Chinese 4 HP diesel pumps with heads of up to 6 meters and costing US$ 400 can irrigate 5 hectares consuming 0.45 liters of fuel per hour. Chinese 1.5 HP petrol pumps costing US$ 75 pump 3 liters per second and consume less than 0.3 liters of gasoline per hour.

[19]Bom 2002, [20]Urrestarazu and Burt 2012, [21]Van't Hof 1998, [22]Bom 2002

Productivity

- Pumps are the weakest element in many irrigation systems in developing countries. Their maintenance state, upon which irrigation efficiency and reliability depend, directly affects yields. Because spare parts are often not directly available on local markets, if the pump breaks, this may result in prolonged water shortages at crucial crop development stages, seriously affecting production and income.

Climate change

- Canessa et al.[23] promoters of the Diesel Pumping Efficiency Program (DPEP), estimated that each pump retrofit would result in 3.57 tonnes less nitrogen oxide (NOx) emissions and 0.20 tonnes less PM10.
- Systems have been developed that allow traditional diesel pumps to run with biodiesel. According to the U.S. Environmental Protection Agency's (EPA) 2010 *Renewable Fuel Standards Program Regulatory Impact Analysis* report, the use of soybean biodiesel could result in 57% lower GHG emissions compared to petroleum diesel, while biodiesel produced from waste grease results in an 86% reduction.
- The latest engines used in agricultural pumping devices are TIER 4 engines. TIER 4 refers to a generation of federal air emissions standards established by the U.S. EPA that apply to new diesel engines used in off-road equipment. Essentially it requires manufacturers to reduce the level of particulate matter and NOx to a level that is 50-96% lower than existing diesel engines. It is important to note that TIER 4 emissions requirements apply to new products only and do not apply retroactively to any existing machines or equipment.

[23]Canessa et al. 2006

Table 1
Some of the organizations active in the field of retrofitting diesel/electric pumps

Organization	Region	Mission	More information
Hipponet	Niger, Mali, Chad, Senegal	Hippo's goal is to help turn low-lift pump irrigation into an affordable, sustainable solution for family farms along Sahelian rivers in West and Central Africa.	www.hipponet.nl
Practica Foundation	India, Bangladesh, Bolivia	Fuel-efficient motor pumps for irrigation and motorized deep-well pumps	http://www.practica.org
Ide International	Bangladesh, Zambia	Fuel-efficient diesel pumps	http://www.ideorg.org
Small Engines for Economic Development (SEED)	India, Bangladesh and Ethiopia	Micro-engine technologies for irrigation	http://smallengines.weebly.com/index.html
Center for Irrigation Technology (CIT)	California	The Advanced Pumping Efficiency Program is executed by the CIT, which delivers pump efficiency tests and retrofits diesel and electric pumps	http://www.pumpefficiency.org

Table 2

Some of the companies manufacturing diesel/electric pumps

Companies	Region	More information
Wuxi	China, Australia	www.wxpump.com.cn/web/en
BSA	India	www.bsatiger.com
Lister-Petter	All over the world	www.lister-petter.com
Hatz	All over the world	www.hatz-diesel.com
Don Hardy	USA	www.donhardyengines.com

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