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Powering Aquaculture Equipment

J. David Bankston, Jr.[1], and Fred Eugene Baker[2]

The choice of a power source for aquacultural production is a choice between electric motors and internal combustion engines. In some instances a combination of electric motors and generators powered by internal combustion engines may be used. Internal combustion engines include diesel, gasoline, natural gas and liquefied petroleum gas (LPG) engines, with diesel being the most common. Each power source has its advantages and disadvantages, many of which are site and application dependent.

Which type of power plant you use will depend upon your particular situation and preferences; however, you should consider the following factors before making your decision:

1. Ability to do the job.
2. Reliability of power source and fuel supply.
3. Initial cost of equipment and installation.
4. Expected useful life.
5. Convenience of operation.
6. Cost and ease of maintenance.
7. Cost to run the power plant.
8. Current and future costs.
9. Safety.

While many of these factors are site specific, this publication is intended to help you analyze your situation.

Typical efficiencies and lifetimes of power plants and accessories are listed in Table 1.

Internal combustion engines

Internal combustion engines supply a significant percentage of power for aquacultural operations. This is largely due to the scattered nature of power needs which may make a low-cost electric power source (electric service) unattainable. Even under these conditions, electricity may compare favorably when total costs for the entire life of the unit are considered. Availability of natural gas service also impacts natural gas fueled internal combustion engines. Diesel, gasoline, and LPG engines can be supplied with fuel from storage tanks which allows considerable freedom in siting the power plant.

The speed of internal combustion engines may be varied if needed (efficiency may suffer), giving them more flexibility in this respect than electric motors. On the other hand, internal combustion engines are sensitive to their duty cycle. Cycles of short duration with lengthy off cycles are particularly detrimental to their performance and longevity because ofsubstantial running time under cold-engine conditions. In

Table 1. Typical efficiencies and lifetimes of power plants.

Type of Pumping Equipment	Attainable Efficiency	Useful Life*
	Percent	
Right-angle pump drive (gear head)	95	15
Automotive engines (gasoline)	28	9
Natural gas or lpg	28	14
Light industrial engine (diesel)	25-37	14
Electric motors	85-92	25

*Based on 2,000 hours per year of use. With proper maintenance and fewer hours of annual use, the useful life could be increased.

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[1] Louisiana Cooperative Extension Service and Sea Grant Program and

[2] Louisiana Cooperative Extension Service, Louisiana State University Agricultural Center.

general, internal combustion engines are best suited to higher horsepower applications with high annual hours of use. Fuel efficiency is usually better for higher horsepower engines (properly matched to load), and the higher fixed cost can be spread over more operating hours.

Selecting an internal combustion engine

Base your selection of an engine as a power source for pumping or similar applications requiring long run times on the continuous service rating rather than on the maximum brake horsepower (bhp) rating. Be aware that many engines are tested without components such as alternators, radiator fans or water pumps. If an engine does not have a continuous rating or its maximum rated brake horsepower is given, use Table 2 to derate the engine for continuous service.

Table 2. Derated engine.

Type of Service	Deduct Maximum Brake Horsepower
	Percent
Continuous load	20
Each 1,000 feet elevation above sea level	0.3
Each 10-degree rise of ambient air temperature above 60 degrees F	1
Accessories (generator, air cleaner, water pump-heat exchanger, etc.)	5
Fan and radiator are used	5
Right-angle drive (if not used in calculating water horsepower)	3
Allowance for wear over time	10

An engine may show substandard performance if it is not loaded properly. An internal combustion engine operates most efficiently at 75 to 90 percent of its continuous horsepower rating at its design speed. Overloading the engine can seriously shorten its life as well as increase fuel costs. Underloading causes inefficient operation.

Diesel, gasoline and propane engines should be sized to the load, whether the load is a generator or an aerator. Properly sizing the power source can improve fuel efficiency. For example, in a situation where a high horsepower (85 hp) tractor powers a small drum (6-inch) paddlewheel, nearly 90 percent of the fuel consumption is required to run the tractor engine and gear train at 1,800 rpm, while only about 10 percent of the fuel is used to turn the paddlewheel and aerate the pond. When the aerator load is increased by deeper paddle depth or the tractor engine rpm is reduced by the proper gearing, the tractor engine is more fully loaded, and aeration accounts for a higher percentage of fuel consumption.

This may be seen in the data of Professor Claude Boyd, Auburn University. This data is presented in Table 3. The Specific Oxygen Transfer Rate (SOTR) is the amount of oxygen put into the water per hour. It is a measure of the amount of aeration that can be accomplished. The horsepower requirements for the 4-inch drum with 4-inch paddle depth are nearly the same for both the 540 rpm PTO and 1,000 rpm PTO. The 1,000 rpm PTO allows the tractor engine to run at a slower speed and still turn the paddlewheel at the same speed. The tractor engine is more fully loaded at the slower speed and its efficiency is higher, resulting in the consumption of only 0.7 gallon/hour for the 1,000 rpm PTO compared to 1.6 gallon/hour for the 540 rpm PTO. When the 4-inch drum is lowered to a paddle depth of 14 inches, the power requirement at 540 rpm changes from 4.9 to 16.9 horsepower - a factor of 3.4. Because the engine was more fully loaded, the efficiency of the engine increased. The SOTR increased from 15.2 to 45.1 pounds O_2/hour, a factor of 3.0; the fuel consumption increased from 1.6 gallons/hour to only 2.0 gallons/hour-a factor of 1.3. Thus, even though the efficiency of the aerator decreased (3.1 to 2.7 pounds O_2/hp-hour), the increased efficiency of the engine more than doubled the oxygen transfer per gallon of fuel (22.6 compared to 9.5 pounds O_2/gallon).

The engine should be maintained in good operating condition. Ignition, timing and carburetion should be adjusted on spark-ignited engines. Diesel engines require fuel injection timing. Have a qualified specialist make adjustments to ensure the greatest efficiency under the operating conditions.

An additional consideration for diesel, gasoline and LPG engines is fuel storage. Storage tanks should be designed to prevent pollution and, if a leak or spill occurs, to permit cleaning up the fuel. For this reason, underground tanks are usually avoided.

Above-ground tanks may need provisions to contain leaks or spills. Check with your appropriate regulatory agency. Fuel loss or adulteration can occur in storage. Fuel loss could occur through evaporation, which is particularly a problem for gasoline and may lead to higher gum content of the fuel. Adulteration can occur by condensation of water vapor from the air or, in the case of diesel, by bacteria which feed on the fuel in the presence of water. Proper precautions such as filters, water separators, and periodic draining of water from the tank should be

Table 3. Test results of two sizes of paddlewheels. (Power source was an 87 hp tractor.)

Aerator	PTO Shaft Speed (rpm)	Paddle Depth (inches)	Tractor Engine Speed (rpm)	Power Reqmt. (hp)	SOTR (lb O_2/hr)	Fuel Consumption	lb O_2/gal	lb O_2/ hp-hr
PTO paddle-wheel	540	4	1,800	4.9	15.2	1.6	9.5	3.1
4-inch drum	1,000	4	950	4.8	15.2	0.7	21.7	3.2
	540	14	1,800	16.9	45.1	2.0	22.6	2.7
	1,000	14	950	16.7	45.1	1.2	37.6	2.7
PTO paddle-wheel	540	4	1,800	12.4	26.0	1.8	14.4	2.1
20-inch drum	1,000	4	950	12.0	26.0	1.0	26.0	2.1
	540	14	1,800	40.2	90.0	3.0	30.0	2.2
	1,000	14	950	39.0	90.0	2.3	39.1	2.3

taken to assure that the fuel delivered to the engine is clean and fresh. Remember, fuel cannot be stored indefinitely; it deteriorates with age. If the fuel is not suitable for use, even after filtration or treatment, it must be disposed of properly to prevent environmental damage.

Electric motors

There are obvious advantages of electric motors if the energy and standby charges are not prohibitive. The electric motor provides ease of operation (flip a switch to start), and long life, requires minimal maintenance and maintains its performance level year after year. In addition, initial costs are usually less than the cost of internal combustion engines. Reliability of electric motors is higher than that of internal combustion engines; however, they can be shut down by the loss of electrical power. This may be a deciding factor if you live in an area that has frequent power losses or you cannot tolerate a loss of power.

If electric motors are being considered, you should contact your power supplier to assist in planning and assessing costs. The amount of power needed is one of the first points to consider. Motors of five horsepower or less can be powered from the usual 220 volt single-phase current supply. Larger motors usually require three-phase, 220 or 440 volt current. Your power supplier can also advise you on the type of starting equipment which must be used and equipment needed to protect against overloads, undervoltage, and short circuits, and on correct wiring procedures and materials for safe installations. Your power representative can also tell you of applicable rate schedules. You might be particularly interested in the availability of off-peak rates, but also inquire about demand charges (charge on peak use of electricity), service charges and other charges which may apply. You might think of demand and service charges as a cost of fuel storage; knowing these charges and your anticipated operating schedule will enable you to estimate your cost per kilowatt hour. This is illustrated with an example later.

As a rule, electric motors need not be derated from the horsepower indicated on the nameplate. Most manufacturers base the horsepower rating on 70º F air temperature and a 10 to 15 percent overload factor. This is a built-in service factor to compensate for varying temperature and voltage conditions. An electric motor should be selected to operate at nearly full load since the motor efficiency is lower when underloaded (particularly at 50 percent or smaller load). Standby and energy costs are also higher than necessary when the motor is underloaded. However, you should not overload the motor. If motor requirements fall between motor sizes, select the larger motor. For example, if power required is 34 hp, choose the 40 hp motor rather than the 30 hp one.

Electric motors vary in efficiency of converting electric energy to mechanical energy. Motors in the 15 to 40 hp range average about 86 percent efficiency; in the 50 to 150 hp range, they average about 90 percent efficiency.

Fuel costs

One of the biggest costs of a power plant that operates many hours is the cost of the fuel. In order to estimate this cost, the performance of the power plant must be known. Manufacturers have performance data for their products. This data was obtained under specified conditions, and for internal combustion engines from the same tests used to determine the power output (not all engines are tested). Data for fully loaded engines is most often available, part-load performance being harder to obtain.

The fuel economy can be expressed in several ways. Electric motors and some internal combustion engines use efficiency. For other internal combustion engines, fuel economy is expressed in terms of power and amount of fuel used. For example, gallons per hp hour and pounds of fuel per hp hour may be used to express an engine's fuel economy. This method is often denoted as Brake Specific Fuel Consumption (BSFC). Of the two, gallons per hp hour is easier to use since we usually purchase fuel by the gallon; however, it is not used as much since there is more variation in the energy content of a gallon of fuel than in a pound of fuel.

Manufacturer's data can give us a starting point for calculating fuel costs, but what we really want is the performance in the field. The best we can do is to estimate. We could use typical efficiencies such as those found in Table 4 which are based upon the energy content listed in the table.

This table corresponds with measurements taken by L. Leon New, Area Irrigation Specialist, Texas Agricultural Extension Service, on existing irrigation pump installations. This data was taken during a period of time lasting nearly two decades from engines fairly well maintained and matched to their load. The 39 diesel units tested ranged in efficiency from 23 percent to 35 percent (average 30.7 percent). Horsepower of these units ranged from 20 to 209 (average 107). Five hundred and sixty-seven natural gas engines were tested with efficiencies from 8 percent to 29 percent (average 20.9 percent) with power output from 15 to 202 hp (average 86). New also tested 185 electric motor installations ranging from 2 to 200 hp (average 69) with efficiency of 60 percent to 92 percent (average 87 percent). New noted that the actual efficiency of electric motors agreed closely with the manufacturer's rating, but that there was greater variability in the performance and ratings of diesel and natural gas engines.

A second way of obtaining efficiencies, if the manufacturers state performance in terms of efficiency, is to derate the fuel efficiency in much the same manner as that for power. The manufacturer's efficiency should be for the same operating conditions you will experience. Table 5 lists some typical derating factors.

Table 4. Typical field efficiencies.

Equipment Description	Typical Efficiency Values	Unit of Fuel	Energy Content
Diesel engines (new or fairly well maintained and matched to load)	27-37%	gal.	Diesel: 135,000
Diesel engines (use tested in field)	18-25%		
Diesel engines (oversized)	7-15%		
Gasoline engines	7-28%	gal.	Gasoline: 124,000
LPG engines	7-28%	gal.	LPG: 92,000
Natural gas engines	7-28%	ccf	Natural gas:100,000
Electric motors	85-92%	kWh	Electricity: 3,412
Generator conversion Efficiency	75-85%		
Gear head (right angle)	90-95%		
Belt drive	85-90%		

For example, suppose a diesel engine with a 37 percent manufacturer's efficiency rating at a speed and load corresponding to field conditions is to be used. The engine is to be derated for a generator, water pump, radiator, and fan and for wear:

Table 5. Typical derating factors for fuel efficiency.

Type of Service	Deduct Efficiency %
Generator	1.7
Water pump	1.7
Fan and radiator	5.0
Right angle drive (if not used in calculating water horsepower)	5.0
Allowance for wear over time	10.0

Item	Deduction From Table 5	Factor (100% - Deduction)
Generator	1.7% deduction	98.3% = 0.983
Water pump	1.7% deduction	98.3% = 0.983
Fan and radiator	5.0% deduction	95.0% = 0.95
Wear	10.0% deduction	90.0% = 0.90

The fraction of the rated efficiency expected under field conditions is:

(generator) x (waterpump) x (fan & radiator) x (wear)

(0.983) x (0.983) x (0.95) x (0.90) = 0.83

Expected Efficiency:

$$(.83) \text{ x } (37\%) = 30.7\%$$

Note that the cumulative effect of the factors was the product obtained by multiplying all the factors. In both the Texas study and Table 4, the engine efficiencies were based on a nominal heating value of 1,000 Btu / ft^3 for natural gas, 124,000 Btu / gal of gasoline and 135,000 Btu / gal diesel fuel. The actual heating value will vary with the fuel. There are two different heating values: the higher heating value (hhv), which includes the heat released in condensing the water vapor in the products of combustion; and the lower heating value (lhv), which does not include the heat released in condensing the water vapor. Since exhaust temperatures are too high for condensation to occur, many manufacturers rate their engines in terms of lower heating values. This should not present a problem as long as consistency is employed in using such heating values; otherwise, an error may result. For example, if fuel cost calculations were performed using the higher heating value of the fuel and an engine efficiency derived from the lower heating value, an erroneously low cost of power would result. This error can be significant as the following example illustrates.

Manufacturer’s data for fuel economy in terms of Brake Specific Fuel Consumption should also be derated with the same factors as used for efficiency. In this case, however, since a lower BSFC is obtained at higher efficiencies, the adjustment is obtained by dividing the BSFC by the total reduction. Another factor that can complicate calculation is that fuel varies. For example, the weight of a gallon of diesel fuel can depend on temperature and the particular blend. If you lack specific information, a value of 7.07 lbs / gallon of diesel fuel and 6.1 lbs per gallon of gasoline may be used.

Example: What is the cost of natural gas per lower heating value therm (100,000 Btu) if the gas is sold for 50¢ per therm (based on higher heating value). The lhv is 932 Btu / ft^3 and the hhv is 1,040 Btu / ft^3.

Solution: The number of cubic feet needed to obtain 100,000 Btu (hhv) is

$$\frac{100{,}000\text{ Btu}}{1040\text{ btu / ft}^3} = 96.15\text{ ft}^3$$

Thus at 50¢ therm (hhv) we get 96.15 cubic feet for 50¢ or a cost of

$$\frac{50\text{¢}}{96.15} = 0.52\text{ ¢ / ft}^3$$

Evaluated at it lhv, we would need

$$\frac{100{,}000\text{ Btu}}{932\text{ Btu / ft}^3} = 107.3\text{ ft}^3\text{ of gas}$$

It is the same gas and costs the same per cubic ft., thus the cost per lhv therm is:

$$(107.3\text{ ft}^3) \text{ x } (0.52\text{¢ / ft}^3) = 55.8\text{¢ / therm}$$

Cost is 11.6 percent higher for a lhv therm than a hhv therm.

Unlike petroleum fuels, the energy content of a unit of electricity (kWh) is constant. The actual cost of the fuel might be more difficult to obtain since various rates and rate components might apply and the cost per kWh may depend upon usage. Your utility representative should be able to help you determine a suitable average cost.

A good idea of the operating cycle is usually needed for accurate determination. As an example, a fully loaded 50 hp electric motor is expected to operate 2,000 hours per year at 85 percent efficiency. There is a 50 kW demand associated with the motor. The electric bill includes a demand charge of \$2.50 / kW / month for each month, whether the motor runs or not. Energy costs are 6¢ / kWh. What is the average cost per kilowatt hour if demand charges are included?

Electrical energy consumption in kwh of an electric motor is:

$$\frac{(\text{horsepower produced}) \text{ x } (\text{hours of use}) \text{ x } (0.746)}{\text{motor efficiency}}$$

Annual energy used is:

$$\frac{(50) \text{ x } (2{,}000) \text{ x } (0.746) = 87{,}882.4\text{ kWh}}{0.85}$$

Annual energy charge is:

$$(\text{kWh}) \frac{\text{cost}}{\text{kWh}} = (87{,}882.4) \text{ x } (0.06) - \$5{,}272.94$$

Annual demand charge is:

$$(50)\ (\text{kW demand}) \text{ x } (2.50) \frac{\text{dollars}}{\text{kW-mth}} \text{ x } \frac{(12\text{ months})}{\text{yr}} = \$1{,}500 / \text{yr}$$

Total annual charge:

$$5{,}272.94 + 1{,}500 = \$6{,}772.94$$

$$\text{Cost per kWh} = \frac{\$6{,}772 / 94}{87{,}882.4\text{ KWh}} = 0.077 \text{ or } 7.7\text{¢ / kWh}$$

If the same motor was used only 500 hours a year the cost would be:

$$\text{kWh used} = \frac{(50) \times (500) \times (.746)}{0.85} = 21{,}941 \text{ kWh}$$

Energy cost = (21,941) x (0.06) = $1,316.46

Demand charges unchanged, $1,500.00

Total cost = $2,816.46

$$\text{Unit Cost } \frac{2{,}818.\ 24}{21{,}941} = \$0.128/\text{kWh} = \frac{12.8¢}{\text{kWh}}$$

Maintenance costs

Maintenance costs are considerably higher for internal combustion engines than for electric motors. The exact costs are difficult to pin down as they depend on duty cycle, cost of labor and degree of maintenance. However, a rough rule of thumb is to assess internal combustion engines a one cent per horsepower-hour maintenance cost penalty in comparison with electric motors.

Equations and example calculations

Table 6. Electric motor facts.

Required	Single-Phase	Three-Phase
Amps when hp is known	$\frac{746 \times (hp)}{E \times (eff) \times (pf)}$	$\frac{846 \times (hp)}{1.73 \times (E) \times (eff) \times (pf)}$
Amps when kW are known	$\frac{1{,}000 \times (kw)}{E \times (pf)}$	$\frac{1{,}000}{1.73 \times (E) \times (pf)}$
Amps when kva is known	$\frac{1{,}000 \times (kva)}{E}$	$\frac{1{,}000 \times (kva)}{1.73 \times (E)}$
kW	$\frac{(E) \times (I) \times (pf)}{1{,}000}$	$\frac{1.73 \times (I) \times (E) \times (pf)}{1{,}000}$
kVa	$\frac{(I) \times (E)}{1{,}000}$	$\frac{1.73 \times (I) \times (E)}{1{,}000}$
hp output	$\frac{(I) \times (E) \times (pf) \times (eff)}{746}$	$\frac{1.73\ (I) \times (pf) \times (eff)}{746}$

Where: I = amperes
E = volts
eff = efficiency (as a decimal)
hp = horsepower
pf = power factor
kW = kilowatts
kVa = kiloVolt amperes

Calculations to determine your energy cost

Electric:

Step 1: Determine the power in terms of brake horsepower (bhp), required by the device (pump, aerator, etc.).

Step 2: Determine cost of power

$$\text{Electric Cost to Operate in \$/hr} = \frac{.746 \times (\text{bhp}) \times (\text{energy cost in \$/kWh})}{(\text{electric motor eff}) \times (\text{drive eff})}$$

Note: These efficiencies should be expressed in decimal form for equations.

Example: 35% = .35. If a component is not used, omit its efficiency from the equation. The energy cost per kwh should include all charges such as demand charges.

Example: What is the cost per hour of electricity to operate a 90 percent efficient direct coupled electric motor producing 40 hp if the cost per kWh is 8¢?

Solution:
$$\text{Cost/hr} = \frac{.746 \times (40) \times (.08)}{.90} = \$2.65/\text{hr}$$

Internal combustion engines

The first step is the same as with electric motors, determine the power required. The second step, determining the cost of power, requires a choice of equations depending upon how the engine's performance is stated. The engine's performance should be derated, as described previously, if required. The third step, which is optional, is to assess a maintenance cost penalty in comparison to electric motors. This procedure is illustrated below using the same horsepower (40) requirement as for the electric motor.

Performance given in terms of efficiency

$$\text{Internal combustion engines cost to operate} = \frac{2{,}545\ (\text{HP})\ (\text{fuel cost in \$/unit of fuel})}{(\text{energy content})\ (\text{power source EFF})\ (\text{drive EFF})\ (\text{generator EFF})\ (\text{electric motor EFF})}$$

Note: These efficiencies should be expressed in decimal form for equations.

Example: 35 percent = 0.35. If a component is not used (example: a generator), omit its efficiency from the equation. If specific energy factors for your fuel are not available, use those in Table 4.

Examples:

(1) New diesel engine sized properly (30 percent eff), 1 right angle gear drive (90 percent), diesel cost $.60/gal.

Diesel cost to operate

$$\text{Cost/hr} = \frac{(2{,}545) \times (40) \times (.60)}{(135{,}000 \times (0.30) \times (0.90)} = \$1.68/\text{hr}$$

Energy content of 135,000 from Table 4

Maintenance cost penalty:

$$\frac{40\ \text{hp}}{0.90\ \text{gear efficiency}} = 42.09\ \text{hp required of engine}$$

In 1 hour engine would produce 42.09 hp-hr which at 1¢/hp-hr results in a maintenance penalty of $.42/hr. Total of energy and maintenance penalty $2.10/hr.

(2) Used diesel engine, oversized (10 percent eff), right angle gear drive (90 percent eff) diesel cost $.60/gal.

Diesel cost to operate

$$\text{Cost/hr} = \frac{(2{,}545) \times (40) \times (0.60)}{(135{,}000) \times (0.10) \times (0.90)} = \$5.03/\text{hr}$$

Same maintenance penalty of $0.42/hr. Total energy cost and maintenance penalty $5.45/hr.

Performance in terms of fuel consumption

If manufacturers' BSFC figures are used, the appropriate second step is to derate to cover actual conditions, and convert to unit of fuel (gallons) per horsepower hour. This is accomplished by:

$$\frac{\text{BSFC (lb/hp-hr)}}{\text{Fuel density (lb/gal)} \times \text{derating factor}} = \frac{\text{gal}}{\text{hp-hr}}$$

If consumption is given in terms of gal/hp-hr, derate to actual conditions.

Example: A manufacturer's engine has a BSFC rating of 0.44 lbs/hp-hr at operating conditions corresponding to our load requirements. The rating was obtained without a radiator, fan, alternator or water pump (all of which will be used) for a new engine. Determine an appropriate gal/hp-hr figure for a derated engine.

Solution:

Condition	**Derating Factor**	**Multiplier (1.0 - Derating Factor)**
Wear	10%	0.90
Alternator	1.7%	0.983
Water pump	1.7%	0.983
Fan and radiator	5%	0.95

Derating factors were obtained from Table 5. Total derating is obtained by multiplying (0.9)(0.983)(0.9830)(0.95) = 0.83. Using 7.07 lb/gal of fuel:

$$\text{Fuel consumption} = \frac{0.44}{(7.07) \times (0.83)} = 0.075\ \frac{\text{gal}}{\text{hp-hr}}$$

The hourly fuel cost is determined from:

$$\textbf{Internal combustion engine cost to operate} = \frac{(\text{SFC (gal/hp-hr)}) \times (\text{hp}) \times (\text{unit fuel cost (\$/gal)}}{(\text{drive eff}) \times (\text{generator eff}) \times (\text{electric motor eff})}$$

Example:

(3) Compute the $/hr cost for the diesel engine in the previous example teamed with a 90% efficient right angle drive for a diesel cost of 60¢/gal. The SFC as derated in gal/hp-hr is 0.075. The bhp output of the right angle drive is 40.

$$\textbf{Cost to operate} = \frac{(0.075) \times (40) \times (0.60)}{(0.90)} = \$2.00/\text{hr}$$

$$\text{Maintenance cost penalty: } \frac{40 \text{ hp}}{.90 \text{ gear efficiency}} = 42.09 \text{ hp required of engine}$$

at 1¢/hp-hr, maintenance penalty would be 42¢/hr. Total energy cost and maintenance penalty $2.42/hr.

Summary

These calculations will provide only part of the costs and factors to consider. Don't forget the factors listed at the beginning of this publication:

1. Ability to do the job.
2. Reliability of power source and fuel supply.
3. Initial cost of equipment and installation.
4. Expected useful life.
5. Convenience of operation.
6. Cost and ease of maintenance.
7. Energy cost to run the power plant.
8. Future energy cost.
9. Safety.

Safety

Your first priority should be safe working conditions and safe working practices. Although a detailed safety discussion is beyond the scope of this presentation, because of its importance a few things will be mentioned.

Safety is important. Many potentially dangerous activities such as tractor use on narrow levees, operating PTOs and moving gears, and the use of electricity near areas of activity and water occur in aquacultural operations. Make certain all safety guards are in place and in good condition, especially on PTO shafts and stub gear. Perform any inspection or service only after equipment is shut down. Refuel only when engine is not operating and is cooled down. Make sure that tractor operators are experienced, especially when equipment is used on levees and around ponds. When using tractors to relocate or place aeration equipment, set brakes securely and block wheels.

Handle fuel with caution. Do not smoke around fuel. Use a vent on your fuel storage tank and make sure the tank is grounded.

For electrical safety, do not drive over wires. This can damage the wire's insulation. Make sure that power is shut off and locked out at the control box before any maintenance work is done. Use qualified electricians to install wiring and avoid a jury-rigged job. Use only approved wiring and follow applicable electrical codes. Your local electrical inspector, supply house, electrician or power supplier may be able to advise you. To prevent rodents from damaging any wiring, place exposed wiring in conduits.

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