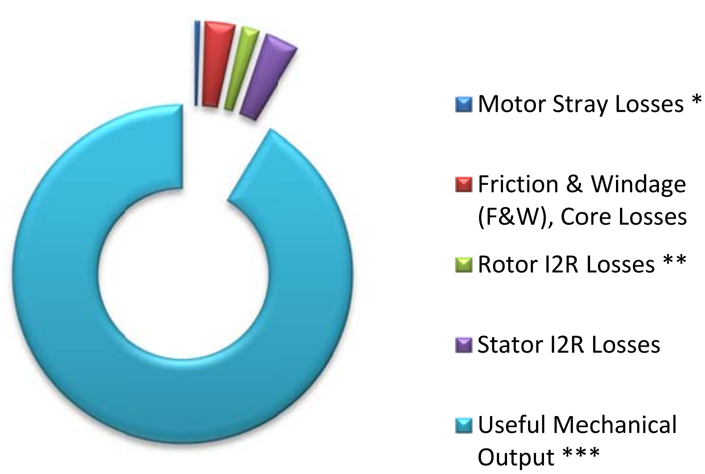
Motor and Control Upgrades as an Electricity Saving Measure

Electric motors, designed for use in various systems, range in efficiency from below 60% to over 90%. Electric motors may be operated at reduced speed if speed or load control features and components are included. Common methods of speed and load control include manual speed switches such as high, medium and low speeds, use of inlet vanes in fans and pumps, use of variable speed drives (VSDs) or variable frequency drives (VFDs) and specialized controllers such as those used in electronic commutated motors application.

High efficiency large motors can operate at 92% or better efficiency[2]. **Chart 1** below shows minor losses in induction motors' efficiencies, which are the most common type of motors used in small and large fans, blowers and pump applications.

Chart 1: High Efficiency Induction Motor

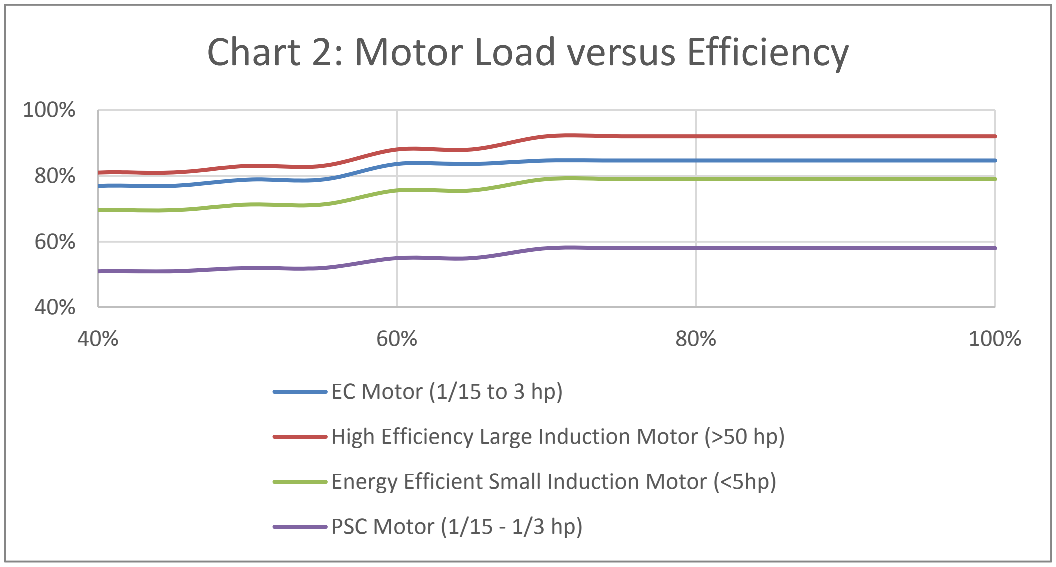


[3]

Thanks to Kazim Yadullahi, PE, CEM, for his assistance with describing the energy-saving measures and providing the charts and tables in this paper.

[2] Measured as electrical to mechanical efficiency

With the exception of small or fractional horse power Electronically Commutated (EC) constant torque motors, which operate at 84% or better efficiencies at various loads, fractional horse power or small motors operate inefficiently. **Chart 2** below shows variation in motors' efficiencies (y-axis) relative to its operations at various loads.



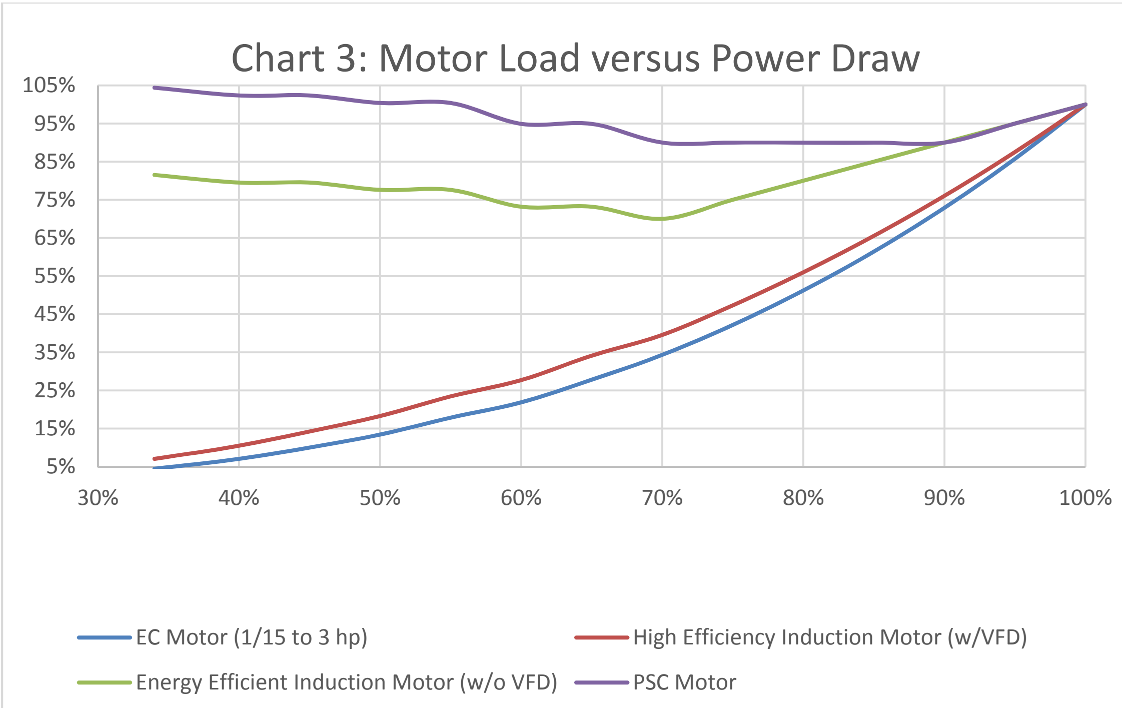
Electric motors commonly seen in small and large refrigeration coolers/freezers, especially those installed before 2013, are often very inefficient. These inefficient motors are of type permanent-split capacitor or PSC motors, and are often not provided with speed or load controls. These inefficient motors dissipate heat into the coolers/freezers causing refrigeration systems and compressors to work harder, resulting in increased wear and tear on compressors and refrigeration system components, energy waste, and costly repairs.

Fans, blowers and pumps driven by electric motors show unique characteristics based on the system design and operation. A performance curve specific to these systems and operations helps identify the optimal efficiencies or "sweet spots" where smooth and reliable operation occurs using lower amounts of energy. The electricity requirement of the motors driving the equipment is closely related to the speed at which the motors' shaft rotates, and the shaft loading.

One fold reduction in motor speed causes three folds reduction in electricity required to operate the motor. This phenomenon is expressed in mathematical equations called fan or pump affinity laws, which

* Stray losses range from 0.5% to 1.8% of motor rated power
** Rotor losses increase with internal slip
*** For fans and pumps, motor useful mechanical output is its shaft power
Stray losses may arise from: (a) Eddy currents in armature conductors (b) Short-circuit currents in coils (during commutation) (c) Eddy currents in bolts/housing (armature - rotors or stators) (d) Hysteresis related losses - magnetic flux pulsations due to reluctance - teeth, slots, commutation - coils and magnetic flux distortion due to armature reaction

show a cubic relation between motor power and the speed at which the motor shaft rotates. **Chart 3** below shows substantial reductions in motor power draw (y-axis) at reduced load and speed using VFDs and controllers with EC motors; notice the increase in power draw of PSC and induction motors at low loads when operated at constant speed.



Motor and control upgrades seen in the video on the 2014 Mathias Ag Program webpage rely on these affinity laws, advancements in the design of motors (such as electronically commutated motors), and specialized controllers, sensors and relays to continually match motor operations with system requirements. These upgrades and controls involve review of the existing system and its operations and measurements-- electrical, physical, and mechanical. Appropriately selected EC motors and controllers or high efficiency induction motors and VFDs, when programmed for specific systems and professionally installed and commissioned, have the potential to save a substantial amount of energy and operational costs while providing reliable operation for a decade or longer.

Table 1 shows the saving potential from a 1 horsepower evaporator motor application in a cooler/freezer (with year round continuous use except during defrost mode of approximately 1.5 hours per day). Lifetime savings of $13,419 per each horsepower of installed fan capacity is substantial and beneficial to small and large businesses alike.

Table 1: Monetary and Environmental Benefits of Efficient Motors and Controllers in Coolers/Freezers

% Operating Hours	% Required Flow (Load)	EC Motor kWh	Induction Motor w/VFD kWh	Induction Motor kWh	PSC Motor kWh
4%	34%	9.2	19.0	219.4	382.7
9%	40%	32.9	63.5	481.5	844.2
12%	45%	62.4	115.0	641.9	1125.6
16%	50%	111.4	196.8	835.3	1472.0
14%	55%	129.8	220.6	730.9	1288.0
13%	60%	147.6	242.3	640.1	1130.7
11%	65%	158.8	252.5	541.6	956.8
7%	70%	124.6	186.3	329.7	577.4
6%	75%	131.4	191.1	302.8	494.9
3%	80%	79.7	113.0	161.5	247.4
2%	85%	63.8	88.2	114.4	165.0
1%	90%	37.8	51.2	60.6	82.5
1%	95%	44.5	58.9	63.9	87.1
1%	100%	51.9	67.3	67.3	91.6
Annual Electric Consumption (kWh)		1,186	1,866	5,191	8,946
Annual Cost of Electricity		$131	$198	$519	$879
Retrofit or First Cost		$1,500	$1,850	$850	$421
Rebates		$ (466)	$ (425)	$ (225)	$ -
Simple Payback (years)		1.4	2.1	1.7	n/a
Life Time Savings		$13,419	$12,220	$6,454	n/a
NPV of Net Savings		$6,473	$5,442	$2,994	n/a
ROI		432%	294%	352%	n/a

Analysis based on 1 hp fan motor typical loading (coolers/freezers compressor savings not shown)

Assumes marginal rates of 9 cents per kWh and $6.5 per kW-billable, average rebates of 6 cents per kWh-first year savings

Assumes annual electric rates escalations at 2.5% and 15 year service life of motors and VFDs

Assumes average commercial business discount or hurdle rate of 6.9% for Net Present Value (NPV) estimates

In commercial facilities and spaces where heating, ventilation and air conditioning (HVAC) systems are used, similar motor and controller upgrades have the potential to reduce energy and operational costs while reducing a facility's environmental footprint. **Table 2** uses the example of a 1 horsepower fan associated with a HVAC system to show the impact of motor and control upgrades on energy and operational costs. The return on investment (ROI) of 114% is impressive.

Table 2: Monetary and Environmental Benefits of Efficient Motors in Buildings' HVAC Systems

% Operating Hours	% Required Flow (Load)	EC Motor kWh	Induction Motor w/VFD kWh	Induction Motor kWh	PSC Motor kWh
4%	34%	3.3	6.7	78.0	136.1
9%	40%	11.7	22.6	171.2	300.2
12%	45%	22.2	40.9	228.2	400.2
16%	50%	39.6	70.0	297.0	523.4
14%	55%	46.1	78.5	259.9	457.9
13%	60%	52.5	86.2	227.6	402.0
11%	65%	56.4	89.8	192.6	340.2
7%	70%	44.3	66.2	117.2	205.3
6%	75%	46.7	67.9	107.7	176.0
3%	80%	28.3	40.2	57.4	88.0
2%	85%	22.7	31.4	40.7	58.7
1%	90%	13.5	18.2	21.5	29.3
1%	95%	15.8	20.9	22.7	31.0
1%	100%	18.5	23.9	23.9	32.6
	Annual Electric Consumption (kWh)	422	663	1,846	3,181
	Annual Cost of Electricity	$62	$89	$218	$360
	Retrofit or First Cost	$1,500	$1,850	$850	$421
	Rebates	$ (166)	$ (151)	$ (80)	$ -
	Simple Payback (years)	4.5	6.3	5.4	n/a
	Life Time Savings	$5,349	$4,856	$2,549	n/a
	NPV of Net Savings	$1,717	$1,103	$693	n/a
	ROI	114%	60%	82%	n/a

Analysis based on 1 hp fan motor typical loading and 8 hrs./day usage (HVAC compressor savings not shown)

Assumes marginal rates of 9 cents per kWh and $6.5 per kW-billable, average rebates of 6 cents per kWh-first year savings

Assumes annual electric rates escalations at 2.5% and 15 year service life of motors and VFDs

Assumes average commercial business discount or hurdle rate of 6.9% for Net Present Value (NPV) estimates