

## Converting Glow Sport & Sport Scale Airframes to Electric Power

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This information is being provided for the experienced glow powered RC flier who would like to convert a glow powered, fixed wing, propeller driven sport or sport scale airframe to one powered by an electric motor with good performance or performance similar to or exceeding the performance of the glow powered plane that he or she is presently flying.

### Getting Started:

The first thing needed when doing a glow to electric airframe conversion is money, a lot of money! The money will be used for purchasing a motor, battery, electronic speed control (ESC), charger, and support equipment. It is very much like starting all over again in the RC hobby/sport. The initial investment will once again be very high, just as it was when entering the hobby as a glow power flier.

To convert a glow ARF or kit airframe for use with electric power requires the use of an efficient brushless motor and Lithium Polymer (Li-Poly/Li-Po) batteries, period. Cheap won't do it! I hesitate to recommend Lithium Polymer batteries, as their usage is still in the "transition" stage from beta user to consumer user friendly in the evolution of the technology (February, 2006). Li-Poly batteries are VERY expensive, but for very good to equivalent or better power and performance, in a typical glow airframe, they are necessary.

### Thinking E-Power:

RC fliers who choose to use electric motors instead of glow engines think about "power" by using **watts in** as a reference and not the cubic inch displacement of the engine as the majority of glow powered fliers often do.

**Watts:** Volts times Amps = Watts

**Watts in** is the unit of choice for measuring the performance potential of an electric power system. It is used because it can be easily measured using a simple device like the Astro Flight Super Whatt-meter (towerhobbies.com \$59.95).



Watts out of an electric motor or even horsepower out of a glow engine is usually a nebulous, estimated number. The only real way to find the power out of a motor or engine is by using a dynamometer.

Many glow powered RC fliers think of "power" in terms of the cubic inch displacement of the engine. While this is "thinking" about engine size, it is a typical way that a glow flier thinks about power.

In thinking of "power" for electric motors **watts in** is used instead of the cubic inch displacement of the engine. To think of the required **watts in**, the glow-powered flier may use the 2-stroke cubic inch glow engine

displacement and multiply by a factor 1000 for good performance and a factor of 2000 for equivalent or better performance.

### **A couple of examples:**

To replace an O.S. 0.61 cu.in. 2-stroke glow engine would require an electric motor that can handle  $0.61 * 1000 = 610$  **watts in** for good performance on a “60” glow powered airframe and  $0.61 * 2000 = 1220$  **watts in** for equivalent or better performance.

A Cox Black Widow 0.049 could be replaced by a brushless electric motor that can handle  $0.049 * 1000 = 49$  **watts in** for good performance and  $0.049 * 2000 = 98$  **watts in** for equivalent or better performance.

**Weight is the key to selecting the brushless motor.** Manufacturer names and designations are useless in motor selection. Use the weight of the brushless electric motor as a guide in choosing the appropriate motor for a given airframe. Use **65 watts in** per ounce of brushless motor weight to figure out how many watts a given brushless motor can handle without being pushed to its maximum potential.

From the above examples:

0.61 good performance 610 watts in divided by 65 watts in = 9.38 oz. motor weight

0.61 equivalent performance 1220 watts in divided by 65 watts in = 18.77 oz. motor weight

0.049 good performance 49 watts in divided by 65 watts in = 0.75 oz. motor weight

0.049 equivalent performance 98 watts in divided by 65 watts in = 1.5 oz. motor weight

**Performance is determined by the amount of watts in compared to the ready to fly weight in pounds.** For good performance with an efficient brushless motor and lithium polymer cells, use **75 watts in** per pound, and for equivalent performance, use **150 watts in** per pound as the performance target. In the majority of conversions, the target will not be met, but still produce very acceptable aircraft.

It must be remembered that this is just a general guideline for sport and sport scale glow powered RC airframes designed to allow the glow-powered flier to think “electrically” for power and performance. While electric motors may not have exactly the same “horsepower” as the glow equivalent, the electric motor usually uses a larger diameter prop, similar to a 4-Stroke glow engine, to provide very adequate to equivalent or better power and performance. In general, a larger diameter prop is more efficient, thus the “feel” and “perception” of the power seems similar or sometimes even better!

### **Choices Are a HUGE Problem**

When the glow flier looks at the myriad of motors, batteries, electronic speed controls (ESCs) and props available, it is all very confusing.

There are many motors, batteries, electronic speed controls and props that can be used in any particular conversion. To reduce the many choices to a few, I have created a simple to use Microsoft Excel Spreadsheet. If you do not have the Microsoft Excel program on your computer, the spreadsheet function in the FREE Open Office suite (<http://www.openoffice.org>) may be used. The Spreadsheet uses a limited number of suppliers and equipment. If you use the spreadsheet, follow the examples, and install the suggested equipment in the glow airframe, you will be successful. The spreadsheet is designed to answer the ever-ongoing question, “What battery, motor and prop do I use?” The spreadsheet does not require any knowledge about how to use a spreadsheet. All that is required to use the spreadsheet is for the user input a few readily available numbers about the glow version of the plane from a manufacturer or supplier’s description.

The spreadsheet is not intended to be an all-inclusive tool. The Data sheet is purposely limited to keep the choices as simple as possible for the new electric power flier. It is limited to a very few brands of motors, ESC’s, batteries and suppliers. All of the brands can be found at many suppliers and the prices will vary. By using these very limited supplies and sources, it is hoped to make the selection of the components and ordering much easier for the RC glow flier converting to electrically powered aircraft.

### **Caution!**

Do not run your new power system until you have a way to measure the volts and amps (Watts) going into the electronic speed control (ESC) (**watts in**) from the battery pack! The measuring device should be considered a **MUST purchase** along with your first power system. You will also need to purchase the type of

connectors that you will be using, so that you can hook the power system measuring device into the circuit between the ESC and the battery. To protect your investment, this type of measuring device is a MUST have.

The motor calculation programs, Electricalc ([www.slkelectronics.com/ecalc/index.htm](http://www.slkelectronics.com/ecalc/index.htm)), Motocalc ([motocalc.com](http://motocalc.com)), and the FREE Drive Calculator spreadsheet (<http://www.badcock.net/motorcalc/>), predict and give a one instance snapshot of what is most likely going to happen given a specific motor, battery, and prop combination. They are not accurate enough to protect your motor, battery and ESC from “over-amping” and possible destruction.

When selecting a Hyperion motor system, I am recommending the Hyperion Emeter as this measuring device. The Emeter reads all of the necessary electrical data as well as being a very good tachometer. Plus, the Emeter can be used to easily set up a Hyperion brand Titan ESC. Setting up the ESC on the Emeter is a very nice feature, and it is very easy to use. Programming any ESC with the throttle stick is a real pain! I recommend that you use another way to program any ESC, whenever possible. Allerc.com has the Emeter for \$89.95 and the ESC to the Emeter cable for \$2.95. If you choose a low power system, under 20 amps, you should also order the optional 20-amp shunt for \$13.95, but it is not necessary and just reads more accurately under 20 amps. The Emeter comes with a 100-amp shunt. The Emeter and cable for the ESC, all that you really need, are \$92.90 at allerc.com.

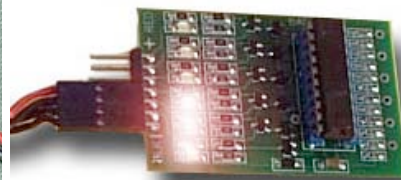


If you want to update the Emeter firmware, and you will, and use the FREE PC software for the Emeter, a Hyperion Titan ESC Program Cable allows you to program the Titan ESC using your computer's serial (RS232) port \$17.95. If your computer doesn't have a serial port, then a USB to Serial Adapter can be had from allerc.com for \$19.95. The Program Cable and Serial Adapter are optional, so the Emeter, ESC to Emeter Cable and 20-amp shunt would cost \$106.85. Put that in your budget, you need it right away!

If you choose to use one of the Model Motors AXI systems, or one of the other suggested motors, purchase an Astro Flight Super Whatt-meter ([towerhobbies.com](http://towerhobbies.com) \$59.95) and a GloBee IntelliTach ([towerhobbies.com](http://towerhobbies.com) \$24.99). If you choose to use a Jeti ESC, you also need the Jeti Advance PLUS Program Card ([hobby-lobby.com](http://hobby-lobby.com) \$7.90) to program the ESC. The Super Whatt-meter, tach and programming card totals \$92.84, just about the same as the Emeter.

### Charger:

There are many Lithium Polymer battery chargers on the market. Get the Astro Flight 109 Lithium Charger for 1-9 Cells at up to 7.5 Amps (\$106.65 @ [towerhobbies.com](http://towerhobbies.com)) and the Astro Flight "Blinky" Battery Balancer (\$24.95 @ [astroflight.com](http://astroflight.com)).



Because Li-Po batteries have an extremely low self-discharge rate, you will only need one charger, so make it a good one!

### Connectors:

Unless you do a lot of motor testing where you are constantly swapping ESC's, the motor to ESC connection is best soldered with the solder joints covered with shrink tubing. During all of the years that I've been flying electrically powered RC planes, I've never once moved an ESC from one motor to the next, except when the system was "retired", and I have only replaced two ESC's, ever in 20 years! Shrink tubing will be needed to cover the solder joints.

For the ESC to battery connections, Anderson Power Poles are the easiest and most convenient to use. For systems drawing less than 20 amps at wide open throttle (WOT) the Castle Creations' 16 gauge ANDERSONS (4 piece set \$3.25 @ castlecreations.com) are very good and the 13 gauge ANDERSONS for 10 amps up to 60 amps (4 piece set \$3.25 @ castlecreations.com).

The Anderson Power Poles can be crimped using the PWRcrimp Powerpole Crimp Tool for \$49.95 from westmountainradio.com. To learn more about connectors check out these articles; [http://www.flyrc.com/articles/using\\_powerpole\\_1.shtml](http://www.flyrc.com/articles/using_powerpole_1.shtml) and [http://www.flyrc.com/articles/connectors\\_1.shtml](http://www.flyrc.com/articles/connectors_1.shtml)



In my opinion, Dean's connectors are very hard to get physically apart and to solder. They also have some known wear issues when repeatedly plugged and unplugged, as in the battery to ESC connection, but a lot of people use them and swear by them. They will do the job.

### Prices of the support equipment to be figured in on the "first purchase":

**Meter/Tach:** \$93

**Charger & Blinky:** \$132

**Connectors & Crimper:** 2 pkg. 16 gauge CC connectors, 2 pkg. 13 gauge CC connectors, 1 PWRcrimp, \$63

**Total:** about \$288

That is right, just about three hundred dollars to get the support equipment you really need. This is an initial expense, except for the connectors; everything is reusable and therefore not a reoccurring expense! If you substitute, it is up to you, but these will do the job that needs to be done very well. If you go "cheap", you will destroy a battery and an ESC. Can you afford that?

### WARNING!

**NEVER** set up or program the ESC with the prop attached to the motor!

**NEVER** run the motor for more than a few seconds without a prop attached to give the motor a load.

**NEVER** run a motor and battery statically longer than necessary to take measurements.

**NEVER** run out a whole battery pack statically, just to see how long it will run.

### Onboard Radio System:

The onboard radio system consists of the ESC, the receiver, servos and receiver battery or receiver battery replacement. For servos, Hitec examples are used on the spreadsheet, but they can be used as a guide for substitutions.

Some specific recommendations for these components can be found in the examples used with the spreadsheet and on the Data sheet.

### **A few things to keep in mind when using the Spreadsheet**

The spreadsheet was created to keep the choices simple by limiting them. Will other items work? Sure. Can you substitute other items? Sure. Should you use only the items from the recommendations? Only if you want to be successful on the first try and not waste your money.

The purpose of the spreadsheet is to narrow down the choices. For motors, there are only five brands of out-runners listed. Are there other great motors? Sure. Will inner-runner brushless motors with gearboxes work as well? Sure. The idea here is to limit the choices! The electronic speed controls in the examples on the spreadsheet were chosen because they work and many can be purchased in combination with the motor to save a few dollars.

Of course there are many great suppliers who are not on the spreadsheet. Again, limiting was done just to keep it simple. If a supplier appears on the spreadsheet it means that they are a trusted supplier. If they are not on the spreadsheet it doesn't mean anything, except that they weren't listed to keep it simple!

### **How the "Spreadsheet" was created**

The motor brands were selected because, for the most part, they have a good, solid reputation. You can learn more about them by reading online forums such as RCgroups.com. The APC prop family was chosen because APC props may be purchased almost anywhere. The batteries were chosen after many days of research, digesting the supplier's specifications, pricing and reading opinions of others on the online forums.

All of the systems put together by the spreadsheet have been tested ONLY "on paper." The systems are set up "on paper" so as not to tax any part of the whole power system: motor, battery or ESC. The formulas used in the spreadsheet should be close enough to "real life" to be of value to the users of the spreadsheet. It must be remembered, that all of the formulas give an approximate value, and real world values will vary.

There is always the possibility of mistyping something, such as prices or other data. Please check with the suppliers for correct pricing, weights, etc. Don't try and say, "Ken said so!" It won't work! I try very hard to be accurate, but mistakes are entirely and likely possible!

### **Estimated Completed Airframe Weights**

The spreadsheet gives the suggested power system component weights along with some anticipated plane and power system specifications. A few specific examples are demonstrated on the spreadsheet. The specific examples demonstrate the appropriate onboard power system and expected completed airframe weight (CAW). The CAW includes everything that is not a part of the power system or onboard radio system. The CAW is important as it determines such things as the weight for the onboard radio components. How to estimate the CAW for most glow planes is one of the calculations of the spreadsheet, so that the modeler can determine the value from available glow plane information.

### **Cubic Wing Loading:**

The term CWL (cubic wing loading) appears on the spreadsheet. There is full explanation of this important topic in the November 2005 *Ampeer* available from Ken Myers at [kmyersefo@aol.com](mailto:kmyersefo@aol.com). The CWL for glow conversions fall into the groups that I have created called:

**Level 4 (Easy Sport)** 7-9.99 oz./cu.ft.

**Level 5 (Sport)** 10-12.99 oz./cu.ft.

**Level 6 (Advanced Sport)** 13-16.99 oz./cu.ft.

**Level 7 (Expert Sport)** 17-20.99 oz./cu.ft.

Basically, the cubic wing loading (CWL) gives a better indication as to how the plane will fly in relationship to others in its group rather than the typical wing loading numbers. The **Level 4** are the easiest to fly of the group, while the **Level 7** require more piloting skills. The spreadsheet indicates the CWL.

### **Using the Spreadsheet**

The spreadsheet is set up to be a simple to use tool with just a few inputs required from the user. The user will need the following information. The information can be found on the Web or in a printed catalog.

## Glow Plane Data Required

A3 - Plane Name:

B5 - Wing Area:

B6 & B7 - Lowest & Highest Manufacturer's weight: (Be sure they are in the correct order with the lowest weight in B6! If only one weight is given, use it in both cells B6 & B7. If the manufacturer's weight is in pounds, enter the formula =16\*weight in decimal pounds in the appropriate cell and the spreadsheet will calculate it as the required ounces. Example: =16\*5 will show 80 in the cell)

B8 & B9 - Smallest & Largest recommended engine displacement in cubic inches: (If only one given, enter it in both cells.)

B10 - Manufacturer's recommended number of functions of the receiver:

B11 - Manufacturer's recommended number of servos:

B51 - Kit or ARF price: (This is entered later, in the budget part of the worksheet.)

## Derived Data for Good Performance:

Once the glow plane data is entered through cell B11, the spreadsheet calculates some values.

B14 & B15 - The cubic wing loading for the glow model, based on the entered data.

B18 - Watts in for good performance. (Based on the average displacement times 1000)

B19 - Target Maximum RTF weight: (Based on 75 watts in per pound)

B20 - Estimated Completed Airframe Weight [CAW]: (Based on the average weight in ounces times 0.65. )

B23 - Estimated Brushless Motor Weight: (Based on 65 watts per ounce of motor weight. Motors are arranged by weight in the motor section of the Data sheet. The weight range to look in is shown in E23 & F23.)

B24 - Recommended Manufacturer Burst Amp Draw: (The manufacturer's burst draw should be equal or higher than this number. The information can be found in the motor section of the Data sheet.)

B25 - Enter number of Li-Po cells in series in pack: (Start at 2. Look at cell B26. 45 amps is really the practical highest amp draw for these types of planes. Actually, 30 – 35 amps is a sweet spot on larger motors. To decrease the required amp draw, increase the number of cells. Before continuing, go to the Data sheet and see if there is a motor with about the right weight that can handle the burst amp draw (B24). If no motors of the required weight can handle the Burst amp draw, increase the number of cells by 1 and see if there is a motor by weight that can handle the burst amp draw (B24).

This sounds more complicated than it really is. Look at example 3 (Exp. 3). The motor weight should be about 0.85 oz. (B23). (The range is given as 0.76 to 1.20 oz. for this example.) If B25 is changed to 2 cells, the burst amp draw B24 is 10. Checking the motor data, none of the motors that are near 0.85 oz. can handle a 10-amp burst. Change the number of Li-Poly cells to 3 and the burst amps (B24) drop to 7. There are several motors of about this weight that can handle a burst of 7 amps or more.

B26 - Estimated Amps: (This is the number of amps that the prop should be drawing on the number of Li-Poly cells chosen to produce the required number of **watts in** (B18).

B27 - Estimated 20C cell mAh: This is the minimum capacity of the suggested cell. If there is not a cell capacity exactly as suggested, round up.

B28 - Estimated Battery Weight: (Based on averaging some known weights)

B29 - Power System Weight (oz.) w/5% fudge factor: This allows for mounts, adapters, props etc.

B32 - Required Minimum in. oz. Torque: (Based on a formula that I came up with, which just seems to work.)

B33 - Hitec Servo Weight: (Based on torque and weight of Hitec servos.)

B34 - Hitec Servo #: (Based on Hitec torque and weight.)

B35 - Number of servos required: Equals B11 – 1 servo, which is replaced by the ESC.

B36 - Weight of servos: Hitec servo weight times number of servos

B37 - Minimum Burst (short term) amps for ESC & Motor: (Actually the same as B24 but this is about the top amp draw the ESC is able to handle.)

B38 - ESC weight: (Based on the recommended Castle Creations ESC.)

B39 - Castle Creations Name: one of the CC Brushless Phoenix ESC's for reference)

C39 – If a high voltage (higher cell count) ESC is required, it is noted here. If a high voltage ESC is required, you have to check the Data sheet to see that the ESC can handle the number of cells. ESC selection may require going to a higher amp rated ESC.

B40 - Receiver weight: Based on FMA receiver as a reference

B41 - FMA Receiver Name: Based on FMA receiver as a reference

B42 - Kool Flight Systems UBEC: If a weight appears in this cell then an external Battery Eliminator Circuit device like the Kool Flight Systems Ultimate Battery Eliminator Circuit is required because the number of cells or number of servos is too high to use the onboard BEC of the ESC. Usually these external devices are used with an optically coupled type ESC or by disabling the BEC on an ESC with a built in BEC.

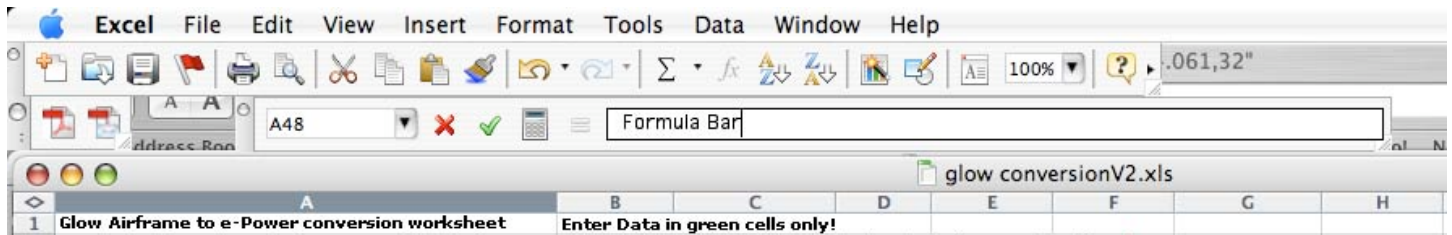
B43 - On-board radio system weight w/20% fudge factor: This allows for the weight of push rods, control horns, servo extensions, etc.

B45 - Approximate RTF weight: Based on the estimated airframe, power system and onboard radio system weights

B46 - Approximate New CWL: Based on the Approximate RTF weight (B45)

### Summary & Budget Good Performance

This is the section where the user inputs personal choices. The choices can be copy and pasted from the Data worksheet. When copying and pasting, paste into the formula bar of the spreadsheet, not the cell. Click on the cell you want to enter the data into and paste the information in the formula bar. The formula bar is near the = sign. The formula bar for Excel on the Mac is shown below, but it is similar on the PC or when using Open Office.



Data from the preceding calculations is presented in white cells, but not changeable, to help in making correct choices.

D51 – Price of the kit or ARF, E51 source or other notes

D52 – Price to “finish” the kit or ARF (figure price of kit for kit or 10% of price of ARF for ARF)

C53 – Chosen motor weight in oz., D53 – price of chosen motor, E53 – name of chosen motor & source

B54 & D54 – Show the motor weight range to look for on the Data sheet.

C55 – Maximum amp draw recommended by mfg. of chosen motor

C56 – Recommended Initial prop from Data worksheet. Purchase several props both “up” and “down” in diameter and pitch and those from other series as well from the recommended props listed on the Data sheet. The best initial prop will be the one that draws closest to the Estimated Amps (B26). Other “close” props should be tested in the air to see which actually provides the “best” flight in the user’s opinion.

D57 – Cost of mount & prop adapter if not included with motor, E56 – note about adapter & source if necessary

C59 – battery capacity from Data worksheet, D58 – cost of pack, E58 – pack description and source

C60 – weight of battery from Data worksheet

C62 – Name of ESC, D62 – Price of ESC, E62 source & other notes about ESC (often there are combos available so the price can be included in with the motor. If a Jeti Advance Plus ESC is chosen, and the ESC was figured in with motor, the Program Card price can be inserted in the price D62 with a note in E62.

C63 – Chosen ESC amp rating

C64 – High Voltage ESC required – Input Yes or No, E63 notes about ESC indicating that it can handle the required number of Li-Poly cells in series

C65 – Weight of chosen ESC

C66 – Servo Description, E65 Servo Brand & source

C67 – chosen number of servos, D67 – Price for all servos, E67 – notes and source for servos  
C68 – Total weight in oz. of all chosen servos combined.  
C69 – Name of chosen receiver, D69 Price of chosen receiver, don't forget the crystal, E69 notes & source  
C70 – Weight in oz. of receiver  
C71 – If external BEC is necessary, weight in oz., D71 cost of chosen UBEC, E71 notes about UBEC & source if required

**Other considerations:**

Summarizes some pertinent data about the user's choices and how they will affect the performance of the aircraft.

The Worksheet then continues with the calculations necessary for a glow equivalent plane and allows the user to once again make choices for the weight and price budgets.

The significant differences for the equivalent performance calculations are:

Watts in for Glow Equivalent Performance: (Based on the average glow displacement times 2000)

Target Maximum RTF weight: (Based on 150 watts in per pound)