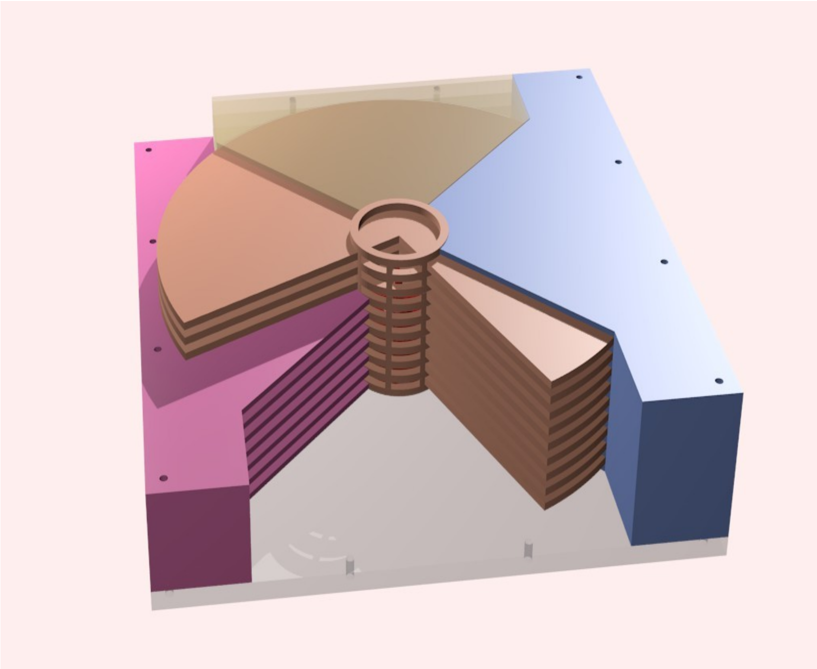
# The Revolution Energy Converter (REC) Explained



## A new way to use an electric motor to move a volume of gas between a heat source and a cold sink to get pressure pulses to generate power

## How the Revolution Energy Converter (REC) works

### Technical explanation

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## Preface

A brand new motor that promises to replace today's polluting combustion engines is being developed. **The revolution Energy Converter (REC)** is the heart of a powerful sustainable heat engine with a wide range of applications. Its simple concept is highly scalable, low cost, zero carbon, making the REC an outstanding competitive solution.
Based on a totally new heat engine technology that builds on established knowledge in heat transfer and thermodynamics controlled by computer logics makes it difficult to compare with existing technology.

To explain this revolutionary concept, allowing the REC to transform temperature gradients into power, the examples below gives a technical step by step illustration:

1. Temperature Difference – effect of temperature difference on a contained gas – the balloon example,
2. Heat Transfer – how to change temperature fast – the grilling sausage example,
3. Control – how to start, accelerate and stop the REC – explanation of the Revolving Shutter (RS) and the “Revolution Dynamic Link” (RDL)
4. Pressure Difference – constant relation between temperature and pressure – the umbrella in the wind and the sealed jar example,
5. Pressure to Energy – explanation of how to use pressure to get energy.

## 1. Temperature Difference

### Example:

Blow up a balloon to full size, put it in the freezer and it will shrink. Taking the balloon back into room temperature, it will expand back into its original size (fig.1). This shows that the volume of a gas, the air in the balloon, changes with temperature.

*Figure 1: Same balloon - different temperatures*

Another example of this phenomenon is to close a jar with a tight lid. As in the balloon case, it contains a closed volume but the size can’t change, instead the internal pressure will change. If we put the sealed jar in the freezer its internal pressure will decrease, however, putting the jar on a hot stove will increase its internal pressure risking exploding. This illustrates that heat change is power, this phenomenon is in the heart of the REC.

### Explanation:

In a closed gaseous volume, the temperature can be used as a measure of energy. When a difference in energy occurs within a system, it will always strive to the least energy state; the heat spontaneously flows from a warm to a cold system to reach equilibrium.
When the gas in the balloon has the same temperature as the ambient air in the room, they are in thermal equilibrium. Putting the balloon in the freezer will start a heat transfer – a flow from a system with high temperature to a system with a lower temperature. Important to note is that all the gas stays inside the balloon, its only heat energy that leaves into the surrounding air inside the freezer. While striving for thermal equilibrium the pressure inside the balloon falls and it shrinks. Energy leaves until the balloon and the freezer reaches the least energy state i.e. thermal equilibrium. When the cool balloon is taken out from the freezer into room temperature, a new heat transfer process starts to reach a new thermal equilibrium. The direction of heat flow is now from the warmer room into the cool balloon. The balloon will expand back to its original size.

**Translated in the REC:**

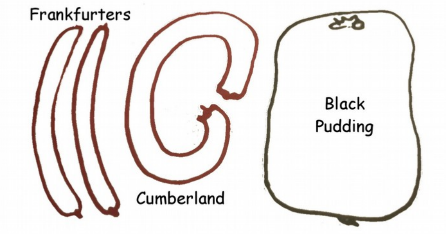
The pressure exerted by a gas in a closed volume is proportional to its temperature.
The REC is a closed system that changes the temperature of its internal volume. It's designed in such way that one side of the converter is connected to a heat source while the opposite side connects to a cold source (heat sink). By changing the temperature of its large gaseous volume, its internal overall pressure will change. The idea is to move the internal gaseous volume between the hot and the cold side, to heat up and cool down the same volume repeatedly, just as illustrated by the examples above.
These pressure changes of the total volume will be converted to power.

The experiments above are the proof of the concept, but they also show that heating up and cooling down a large gaseous volume is a time-consuming process. How could we speed up the temperature change? Let's light up the BBQ...

## 2. Heat Transfer

**Example:**

Put two Frankfurters, a Cumberland sausage and a thick black pudding on the BBQ. The thin Frankfurters are quickly grilled, the Cumberland sausage takes a bit longer as it's a bit thicker, the black pudding will take ages because of its thickness. However, if the black pudding is cut into thin slices, thinner than both the Frankfurters and the Cumberland, it becomes the fastest to prepare.




**Explanation:**

The heat transfer in the REC, a sealed container, works with the same slicing principle. The REC is holding a column of thin slices (*fig. 2*) of a gaseous volume and will move these slices between conducting fins of a heat-conducting block (*fig. 3*). All the gaseous slices will simultaneously get heated on both sides as they pass between the conducting fins.

The thin gaseous slices with large area heat up very quickly and the heat transfer is equally boosted by circulating vortexes inside each flat slice of the gaseous volume (*fig. 2*).

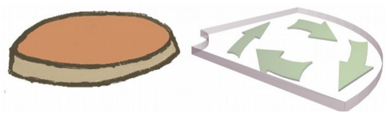


*Figure 2: Comparison of a thin slice of black pudding grilled on both sides with a slice of a gaseous volume heated on both sides in the REC.*

*Figure 3: The thin slices of the gaseous volume passes between the conducting fins of a hot block where they heat up quickly.*

The REC also has a cool conducting block, just like the hot block in figure 3, but with a lower temperature (fig. 4). Moving the column of the thin gaseous slices over to the cool side, the whole volume equally cools down very fast while passing between the cool conducting fins.

**Translated in the REC:**
The closed REC system repetitively heats up and cools down the large sliced column of the gaseous volume to create changes in its internal pressure (e.g. jar example). The column of the gaseous volume is also the only carrier of heat from the hot block to the cold block. The direction of heat transfer is from the hot block where the heat is transferred from the large areas of the hot conducting fins into the column of gaseous slices and the pressure rises. The hot slices are then

simultaneously shovelled over the cold block to transfer its heat to the large areas of the cold conducting fins that will lead away the heat and cool down all the slices and the internal pressure will fall. Once the column of the sliced volume is cooled down, it's shovelled back to the hot block where heat transfer starts from the hot conducting fins to the thin gaseous slices and the internal pressure rises again.

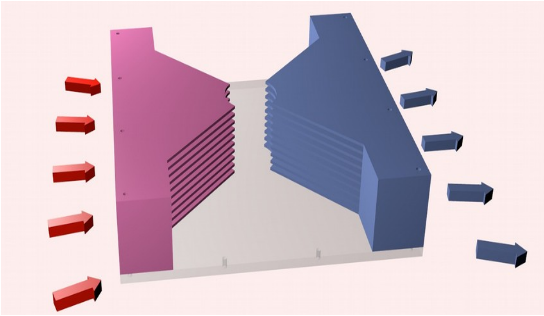


*Figure 4: Conducting fin blocks for heating and cooling the column of the sliced gaseous volume to create internal pressure changes. The direction of heat transfer is from a region of high temperature to a region of lower temperature. Arrows show the transfer of the heat of the volume from the hot block to the cool block where the slices dump their heat.*

Thin slices with large area heats up and cools down faster than thick volumes. The REC is a closed system that heats up and cools down a large sliced volume efficiently, fast and repetitively which results in internal pressure changes.

Following sections will explain how the gaseous column is shovelled between the hot and cold blocks and how to get important use from the pressure changes.

## 3. Control

### Inside the REC:

The closed REC uses an internal **"Revolving Shutter" (RS)** to move the sliced gaseous volume column between the hot and the cold block to create internal pressure changes. The RS (fig. 5) is a pack of disks with a quarter opening "the sliced volume".
All the slices of the gaseous column are held within the quarter opening (fig. 6). When the RS rotates, it moves all the slices of volume between the hot and the cold conducting fins (fig. 7). The RS is not in contact with the fins and is free wheel turned by a controller with logics and an electric stepper motor. The turning of the freewheeling RS and thereby the flow of the sliced gaseous volume does not require very much force to rotate. Although the RS purpose is only to swish around gas, it must be controlled at every instant.

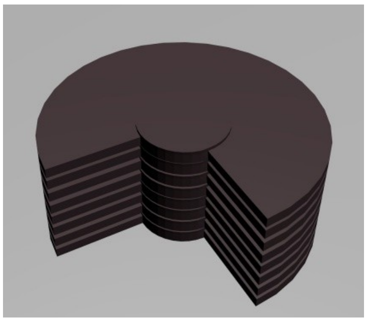


*Figure 5: Illustrates the free wheeled RS with its quarter opening which passes between the conducting fins.*

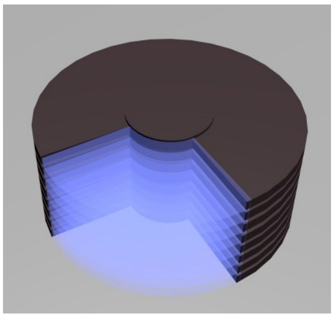


*Figure 6: Illustrates the sliced gaseous volume column, in blue, contained within the RS*

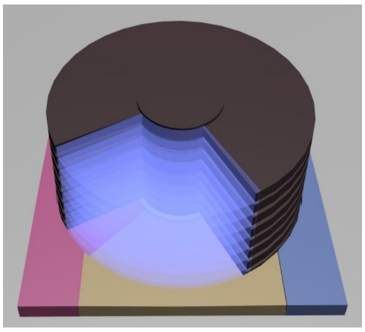


*Figure 7: The sliced gaseous volume is rotated between the hot and the cold block. Only bottom fins of blocks are showing.*

The controller is called the **"Revolution Dynamic Link" (RDL)**. The RDL software is continuously adjusting the RS speed according to input from the running application. It's designed for variable speed as well as varying work load. The RDL is also used in constant speed applications since it adds the great advantage of total control of start and stop and keeping an exactly specified speed.

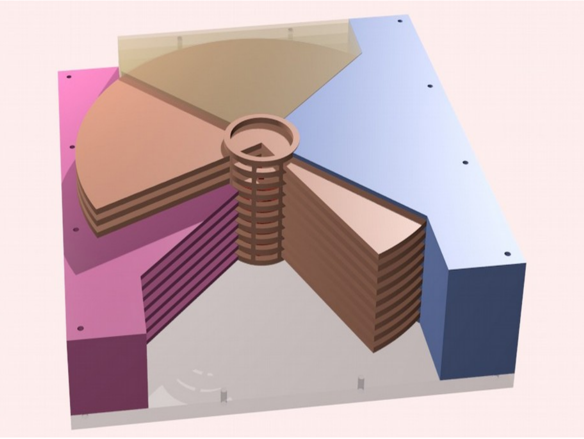


*Figure 1: A view of inside the REC with the hot and cold blocks and their respectively conducting fins in red and blue, the electric operated RS in brown with the quarter openings which contain the slices of volume described in fig. 6. The hot and the cold blocks are separated by insulating nil blocks in transparent beige. The second nil block (placed opposite) has been removed in order to see the RS opening.*

The RDL software controls the internal RS (fig. 8) shovelling the volume slices between the hot and cold fins.
As heat travels from high to low temperature, all spontaneous heat transfer between the hot and the cold side need to be blocked with insulation as the heat must only be carried by the column of thin slices within the RS.
To prevent leakage within the slices, they are not supposed to be in contact with the hot and the cold side at the same time therefore no overlapping is allowed.
To prevent unwanted efficiency leak, the REC contains two insulating "nil blocks" (fig. 8) with insulating fins placed in-between the hot and the cold block opposite each other. The insulating nil blocks prevents to simultaneously heat up and cool down a part of the same volume.

## 4. Pressure Difference

### Example:

The pressure exerted by a fixed volume of a gas is proportional to its temperature. It means that a certain temperature difference always results in a certain pressure difference for a gas in a fixed volume, no matter the size of the volume.
A 1L jar filled with air and tightly sealed with a lid in room temperature of 20°C is heated to 100°C. The internal pressure will rise from ambient room pressure of 101kPa (kilo Pascal) to 129kPa.
In the same way, a larger 10L jar filled with air and tightly sealed in 20°C is heated to 100°C. The internal pressure of the jar will equally rise from 101kPa to 129kPa.
This example stresses that the pressure difference in the two different containers remains equal. Why bother using a large jar (larger volume) when the pressure difference only depends on the temperature difference? This is a very valid question!

Pressure is the amount of force acting per unit area (newton per square metre) and is measured in pascal (Pa). Consequently, having the pressure to work on a larger area will result in a larger force.
If you are walking against the wind in rainy weather and fold out an umbrella, the wind will almost blow you away until it has turned your umbrella into a funnel, useless for rain protection.
This example shows the wind pressure wasn't really bothering you until you exposed it to the large area of the umbrella. The same pressure, but acting on a larger area – will almost blow you away. The broken umbrella with a reduced area, would allow you to walk steady, though you get wet.

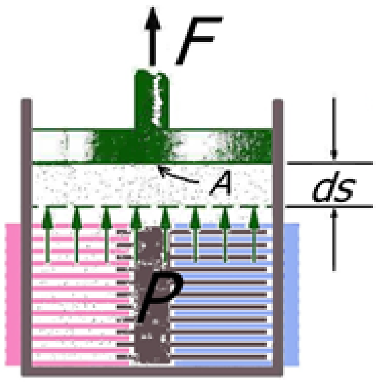
### Explanation:

The formula "Pressure times Area equals Force" and the schematic figure (fig. 9) are at the base of the REC ; $\boldsymbol{P \cdot A = F}$ where $\boldsymbol{P}$ is pressure, $\boldsymbol{A}$ is the piston area, $\boldsymbol{F}$ is the force perpendicular to the top area of the piston.

### Translated in the REC:

When the internal pressure of the REC becomes higher than ambient the piston is pushed outwards. This happens when all the volume slices are between the hot fins, i.e. the shutter opening is on the hot side (fig.9). When the shutter opening moves the sliced column of the volume over to the cold block, the internal pressure will fall, and the outside ambient pressure will push back the piston in the other direction. This force is usable in both directions.

The lower the temperature difference, the lower the internal pressure. This compensates by adding volume and using a large piston area, as shown in the formula ***P · A = F***




At high temperature differences, e.g. when burning raw methane gas, the REC can be built small and compact, suitable for transports in general (car, bus, truck etc.)
At lower temperature differences, like waste heat recovery or solar heat, the REC may be built in very large stationary units with a larger volume and piston area, still able to deliver great power (power plants for electricity) but from a low temperature difference.

*Figure 9: **P** is the REC internal pressure. **A** is the piston head area. **F** is the force you get. A larger piston area (**A**) delivers more force (**F**) but requires a larger REC volume to move the same displacement (the RS opening is on the hot side in this illustration).*

## 5. Pressure to work in the REC

### Inside the REC:

The REC with its logically controlled revolving shutter, RS, is a closed system. A "moving boundary" is introduced to the system by connecting a piston or a membrane to the REC. This will allow for volumetric changes inside the closed system, which in turn will create a force. As the moving boundary reciprocates because of the changes in pressure, boundary work, or simply work, is generated. How work is generated by a moving boundary in a closed system can be described by classical thermodynamics.
A schematic of the conversion from heat to work in the REC, described above, is illustrated in fig. 9. Each of the volume slices in the column, are placed on the hot side of the REC (horizontal white straps). As the volume is heated, the build-up in pressure difference forces the boundary to move and generate work. All the slices in the column builds up one single work generating volume.

Extracting work from heat is step-wise described in the following paragraph:

1. The electric controller motor positions the opening of the RS (c.f. fig 6.) to overlap with the hot block of the REC,
2. heat-transfer from the hot fins into the slices of gaseous volume takes place,
3. the internal pressure (***P***) of the REC rises and forces the piston, with area (***A***), to move a given distance (***ds***),
4. the controller motor turns the slices of the work generating volume (RS openings) to the fins on the cold side where they will dump their heat,
5. the internal pressure drops and the piston returns to its original position, i.e., pushed back the distance ***ds***. The process restarts from 1

Since the 2$^{nd}$ law of thermodynamics dictates that the direction of heat transfer is from hot to cold, it's possible to control the heat transfer between the work generating volume (RS openings) and the fins. In this manner, the pressure drop within the closed system can be controlled. As mentioned, the effect of the internal pressure change of the REC is a displacement of the piston distance, here denoted ***ds***. During this event, work is performed on the piston and this is the reason why the white slices of the gaseous column in fig.9. is called the **work generating volume**.

Work ***(w)*** is performed when a force ***(F)*** is applied and displaces an object over a distance ***(ds).*** In classical mechanics, the formula for work thus becomes ***w = F · ds.*** The pressure is the force acting on unit area, and the expression for work can be rewritten ***w = (P · A) · ds.*** The change in work generating volume, denoted $dV_W$, is directly coupled to the work, since $dV_W = A \cdot ds$, meaning we once again can rewrite the expression for work $w = P \cdot dV_W$.

To translate work to a more useful quantity, power ($P_W$) is used (where $w$ denotes the power extracted from work). The amount of work that is carried out at any instant may be expressed in power, by the expression $P_W = w / t$, where $t$ denotes the time interval. Since the unit of work is in joules and time is in seconds, power is expressed in joules over time or, more commonly, in **watts**.

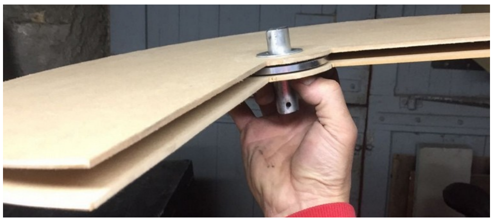
The low pressure is compensated with a large piston surface. To feed a large piston a large volume is needed. To facilitate pressure distribution, this large piston area is a side parallel with the RS of the REC (c.f. fig.9). In theory, there is no physical size limitation for the REC; this means that if the work generating volume increases, more work can be extracted.

If it wasn't for the RDL, the stepper motor could easily continue to turn the RS in any speed even if a heavy work load has blocked the moving boundary, the piston, from moving. The RS is totally independent of the work load and is not affected by the conditions of the moving boundary supposed to deliver the work. That is why the dynamic link is needed to control the stepper motor of the RS. The Dynamic Link keeps track of the RS angle and the work output piston position and/or flywheel angle as well as its load.

## 6. Proof of concept

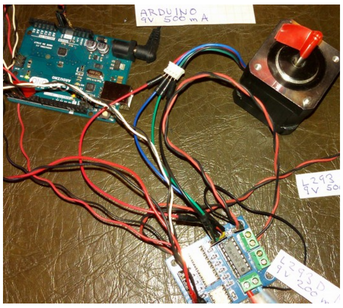
So far, a thermodynamic approach to understand and how to get an idea of how the REC might perform. The description of this revolutionary heat engine on paper is not exciting enough to show how unique and fabulous the REC really is. To convince the world, a proof-of-concept or a prototype must be built, to run, test and proof its capabilities.

At the moment, a simulation helping to calculate the amount of energy that the work generating volume can absorb on the warm side as well as a calculation on how much of this absorbed energy can be dumped on the cold side is ongoing. The work generating volume absorption of energy on the warm side should balance with the work generating volume dumping of energy on the cold side. Understanding and calculating this energy, helps to dimension how thin the work generating volume should be as well as the thickness of the fins.
A simpler "demonstrator" has been built to visually demonstrate the concept while searching for ways to fund the building of an advanced prototype that will verify expectations. The demonstrator uses only three fins (hot and cold) for the heat transfer in and out of the work generating volume of the RS in two layers (pic. 1). There is a valve and an analogue pressure meter (pic.2) to test and make sure that the volume is closed and tightly sealed.



*Picture 1: A two-layer revolving shutter RS with cut out quarter openings to carry the work generating volume*

*Picture 2: The Revolution Energy Converter demonstrator. A theoretical 3D model can be seen at the right in the picture to indicate the placement of the hot and cold fins.*




*Picture 3: The "Revolving Dynamic Link" control system*

*Picture 4: Sealing cap covering vital parts of the "Revolving Dynamic Link" control system.*

These will be replaced by electronic sensors connected to the "Revolving Dynamic Link" (pic.3) that controls the 2-layer revolving shutter. The RDL control system is under the sealing cap shown in picture 4.
This very basic demo model has in its first test runs delivered very distinct pressure pulses already at 30°C temperature difference.

For the first prototypes built, low power stepper motors are considered and a versatile controller like the Arduino which is a well-known prototyping tool that can be bought off-the-shelf. A USB downloadable controller facilitates experimenting. A computer is connected to this, like the Raspberry PI 3 with a free open development platform for the "Revolution Dynamic Link" software. The stepper motor totally controls the revolving shutter that runs freely inside REC independent of power output, so it is totally relying on feedback data from the powered application, i.e. "Revolution Dynamic Linking".
Planned tests for the prototype are how the heat transfer relates to the speed of the RS and how the expected pressure variations relate to the revolving speed. These tests will be done in a series of temperature spans.
If the prototype succeeds in delivering useful data in these first tests, the next set-up will be to measure power output for the same series of temperatures.
Moreover, the same prototype might deliver the following series of tests consisting of a work generating volume containing a vapour close to its condensation to understand how a partial phase shift of a vapour will affect pressure and rotating speed in narrow temperature spans.

## Want to know more or any questions?

Please contact Nils Karlberg for any further information or technical questions about of the REC; nils@nilsinside.com