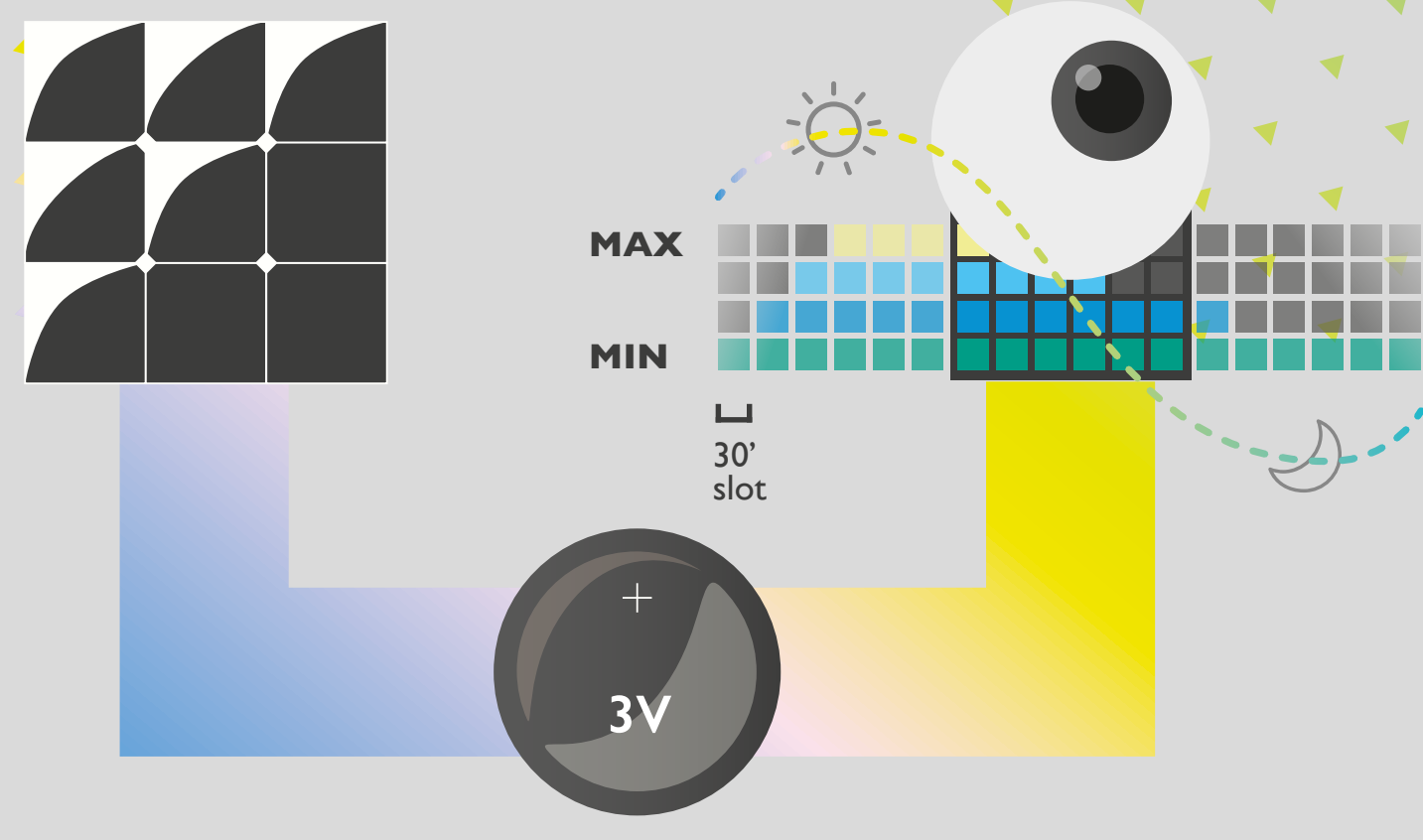
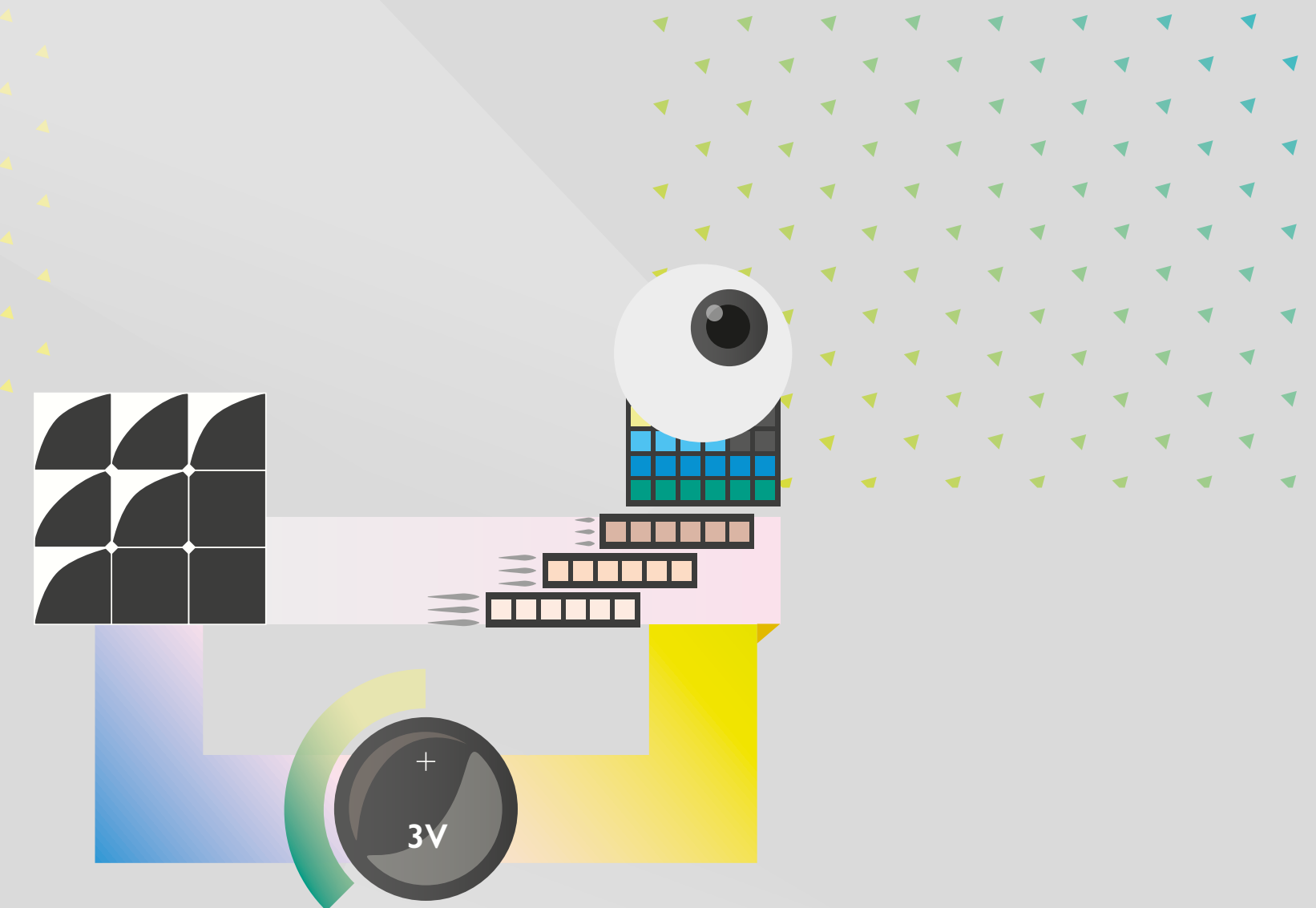


Understanding ENO



Tasks
There is a minimum and a maximum of tasks, such as measurements, that the node can perform. The ENO algorithm must decide the amount of work it can perform between these 2 values, based on the amount of energy available.

Don't waste surplus energy
If it's a sunny day and the battery is full, ideally use the surplus energy to complete extra tasks, such as data encryption, recalibrate the sensor, clean the sensor (actuation), do a diagnostic. This is called residual waste energy



Make sure the battery never empties
If it's a short, winter day, with cold temperatures affecting the battery, rendering it less efficient, the system must make sure the battery has enough charge to last through the night and still complete the minimum tasks required.

ENO

Energy neutral operation balances energy generated and consumed by a system in order to ensure there's always energy available.

ENO+BCP

Once the ENO system now works for each node, the next step is to integrate it with the BCP network. Instead of each node calculating its own battery health and working to maximize that, what is desired is a mesh networking version. As well as deciding transmissions and sensing together, the nodes would also decide on battery health together, in order to make the whole

network last longer. The nodes would effectively trade health.

The aim is to get the nodes talking to each other and make sure they last for the same amount of time. This would make the process of replacing the batteries cheaper and less time consuming, because they can all be replaced in one go.

In a BCP network, each node knows its condition and that of its nearest neighbours. It then decides which one to forward its information to, based on energy cost and bandwidth. This method might be less direct, but is more efficient in terms of power usage when scaled up. It requires less communications to keep the system updated.

ENO & BCP

Understanding battery degradation



Batteries are electrochemical. They degrade with:

Use
Every time you charge and discharge a battery, it's ability to hold the charge degrades.

Time
A battery sitting on the shelf will degrade naturally.

And are influenced by weather conditions

On paper a battery may hold 1000mA, but if it's 10 degrees cooler, it's actually only 900mA. The development of batteries has run parallel to the development of mobile phones, therefore they have been tested, and operate, in human friendly conditions, near 25C. Emerging IoT use cases have broader operational parameters, meaning these assumptions no longer hold true.

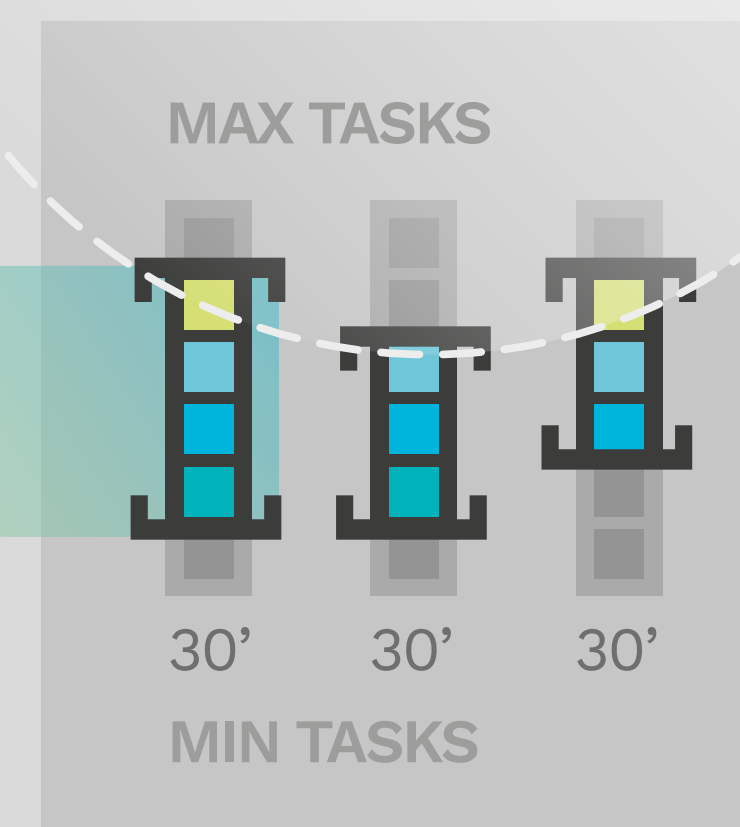
ENO

State of health of the battery



NEW MAX

NEW MIN



PLET

The PLET battery health estimation model has been adapted to work in a sensor node. It uses the Ein and Eout values to calculate the maximum capacity of a battery in real time. Despite the model's simplicity, it's applicable to all battery chemistries and it's over 90% accurate.

Using the PLET model as an input, an algorithm has been developed to extend the lifetime of energy harvesting sensor nodes. Results show sensors can last 4 times longer in the field without a reduction in overall performance.