# Our approach… ?

Sustainable Cyberphysical Systems

Newton’s law of cooling (Differential)

$$\frac{dT(t)}{dt} = -r(T - T_{\mathrm{m}})$$

$$T(t) = T_{\mathrm{m}} + (T_0 - T_{\mathrm{m}})\, e^{-rt}.$$

Newton’s law of cooling (Solved)

$$T(t) = T_{\mathrm{m}} + (T_0 - T_{\mathrm{m}})\, e^{-rt}.$$

| | |
|---|---|
| $T(t)$ | **Final temperature of the piece** |
| $T_m$ | **Ambient temperature (temperature of the oven)** |
| $T_0$ | **Initial temperature of the piece** |
| $t$ | **Time (time inside the oven)** |
| $r$ | **Proportionality constant (dependent on the piece material)** |

$$T(t) = T_{\mathrm{m}} + (T_0 - T_{\mathrm{m}})\, e^{-rt}.$$

$$\Downarrow$$

**Solving for "r"…**

$$r = -\frac{\ln\left|\frac{T(t) - T_m}{(T_0 - T_m)}\right|}{t} \qquad (1)$$

**Solving for "$T_m$"…**

$$T_m = \frac{T(t) - T_0 e^{-rt}}{1 - e^{-rt}} \qquad (2)$$

**Using…**

$$r = -\frac{\ln\left|\frac{T(t) - T_m}{(T_0 - T_m)}\right|}{t} \quad (1)$$

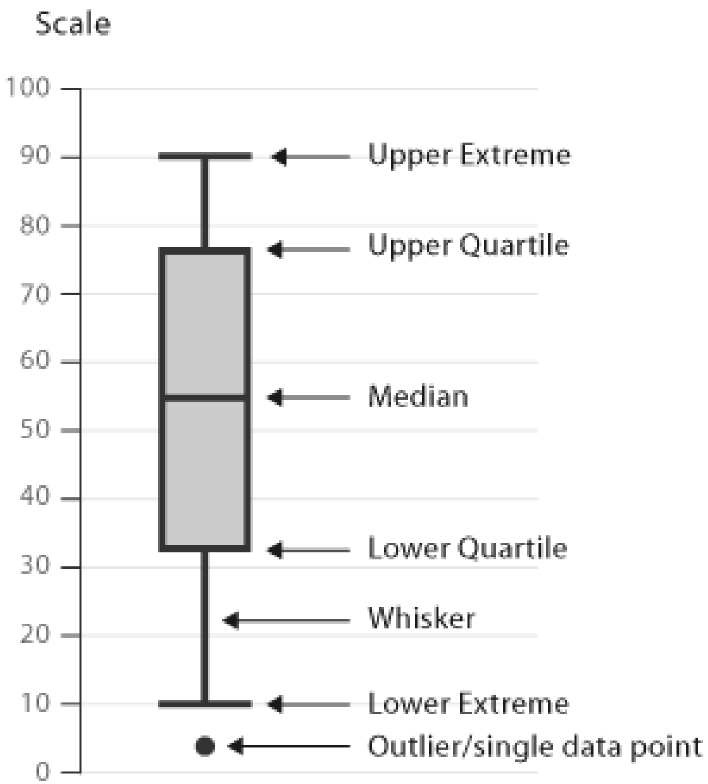
**We run some tests in order to determine "r" through different conditions***

| Test N° | $t$ | $T_m$ | $T_0$ | $T(t)$ | $r$ |
|---|---|---|---|---|---|
| 1 | 200s | 30° | 22,9° | 28,8° | 0.00532 |
| 2 | 250s | 40° | 21,3° | 31,4° | 0.00551 |
| . | | | | | |
| . | | | | | |
| . | | | | | |
| 9 | 150s | 32° | 22,0° | 27,3° | 0.00538 |
| 10 | 300s | 27° | 21,5° | 25,9° | 0.00542 |

*** "r" should remain constant through every iteration, but because the temperature in the oven changes very slightly over time, we are going to obtain slightly different values each time.**

**Using the values for “r” obtained, we build a box and whisker plot to help us determine the best real value for “r”.**

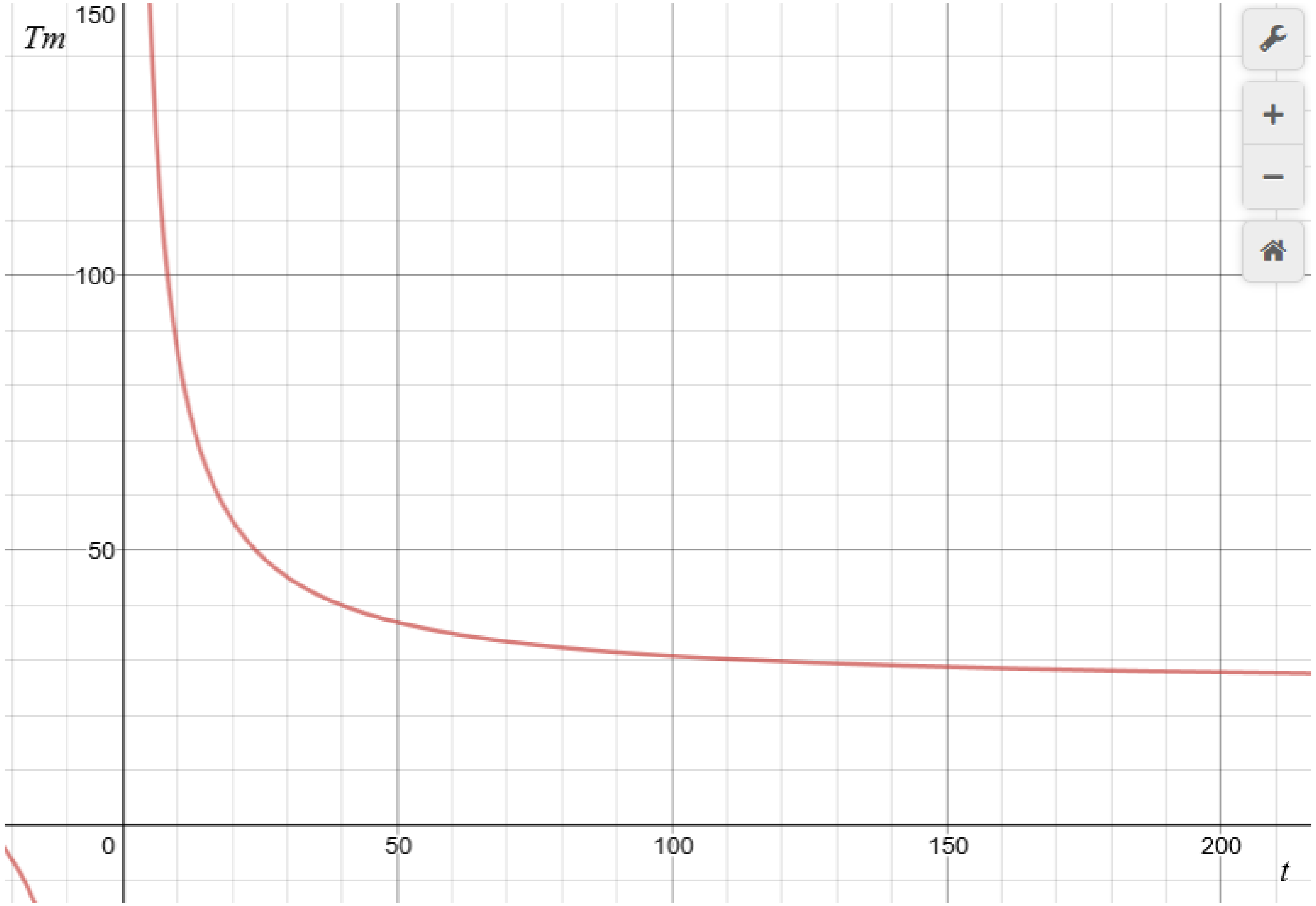
| $r$ |
|---|
| 0.00532 |
| 0.00551 |
| ⋮ |
| 0.00538 |
| 0.00542 |




$$r \approx 0.00531$$

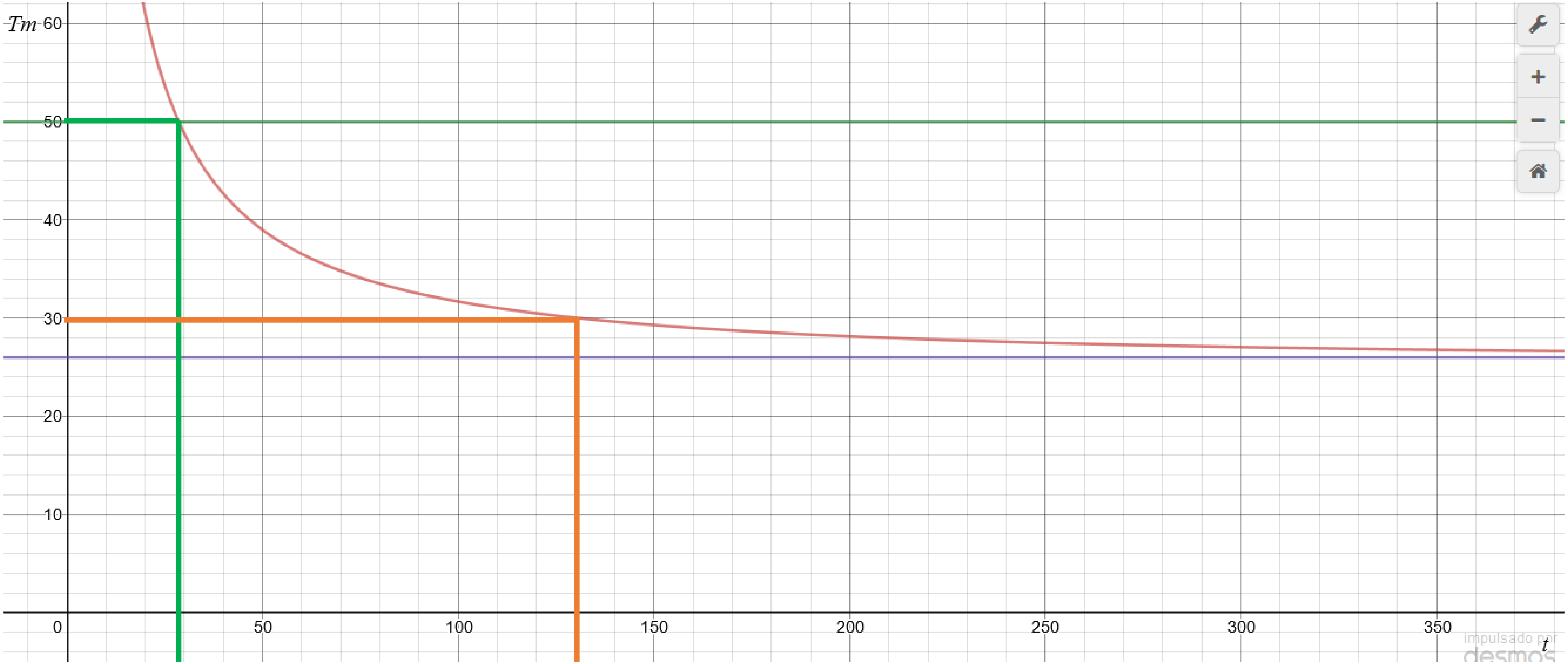
**Using the new value of “r” and equation (2), we can plot a curve that describes each possible combination of time and oven temperature that will result in a final temperature of 26° * ****

$$T_m = \frac{T(t) - T_0 e^{-rt}}{1 - e^{-rt}} \quad (2)$$



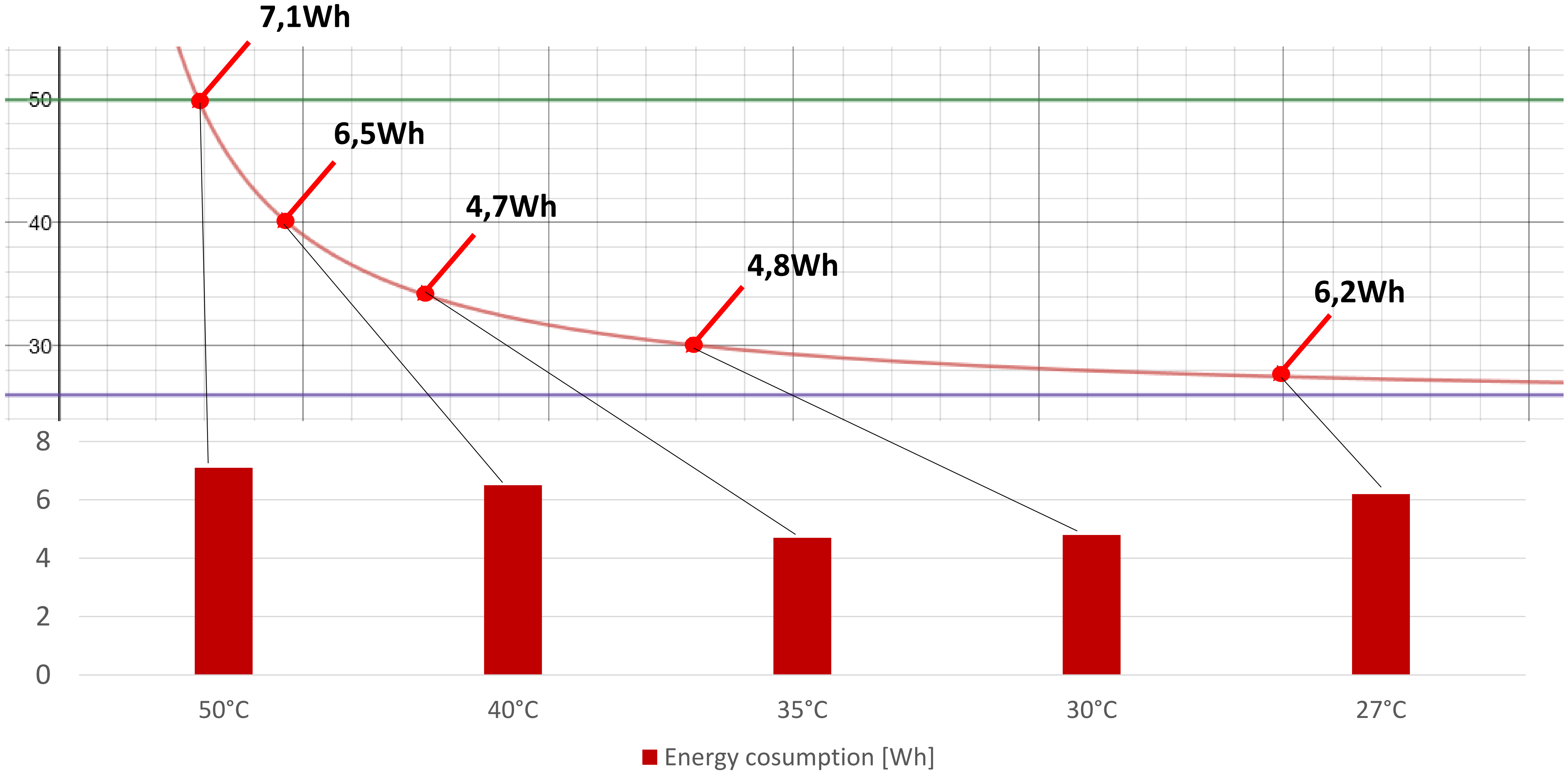

*** Final temperature of the piece $T(t)$ is set as a constant to 26°, our goal.**

**** There will be a different plot for every different initial temperature.**

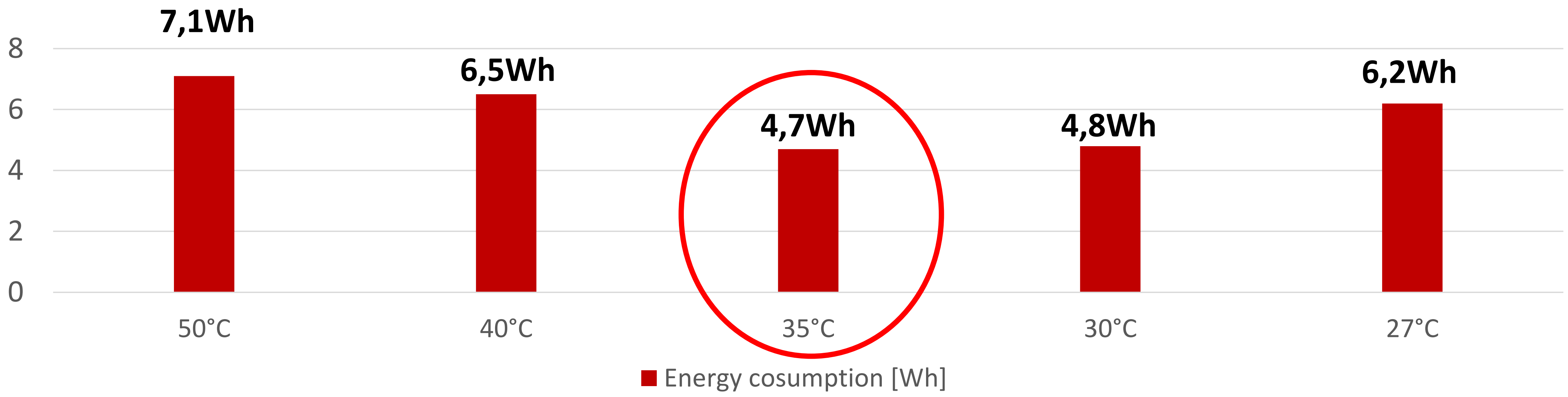



28s @ 50°C 132s @ 30°C . . .

**After this, we can run another set of tests in order to determine the amount of energy consumed on each point in the graph, and then we make a bar graph to visualize the results**



## We analyze the results and determine the optimal temperature and time that will result in the lowest energy consumption *




Lowest power consumption (4,7Wh) → **70s at 35°C**

*** We may need to do benchmarking on each different initial temperature, but we could use regression to approximate the optimal data on each case**

**Of course, all of these are predictions and approximations that may be far from the truth.**

**In theory, “r” should be constant, it may not be, and the Time/Temperature plot formed could be inaccurate.**

**All of these tests have to be carried out for plastic and for aluminum, and we would still need to figure out the implications of heating up pieces in succession.**

**But for the most part, I believe this is the best chance we have yet.**