The logic of Null hypothesis statistical testing

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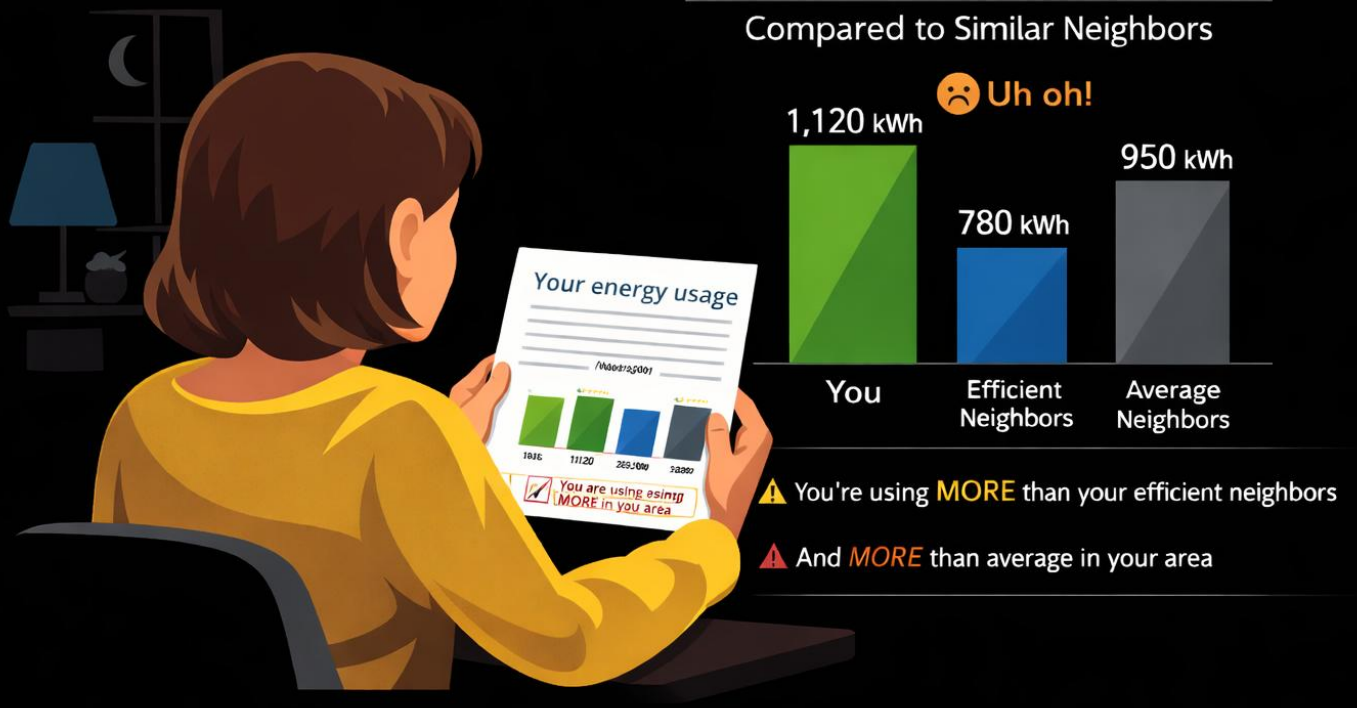
Research question

💡 Can a Social Comparison Nudge Reduce Electricity Consumption?



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Step 1: Formulate a Hypothesis

Hypothesis: A testable answer to the research question

In our case: Social Comparison Nudge Reduces Electricity Consumption

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•Step 2: Specify null and alternative hypotheses

Statistical hypotheses: Statements about <u>populations</u>

<u>…</u>often expressed in terms of population parameters (mean μ, proportion p, variance σ ...)

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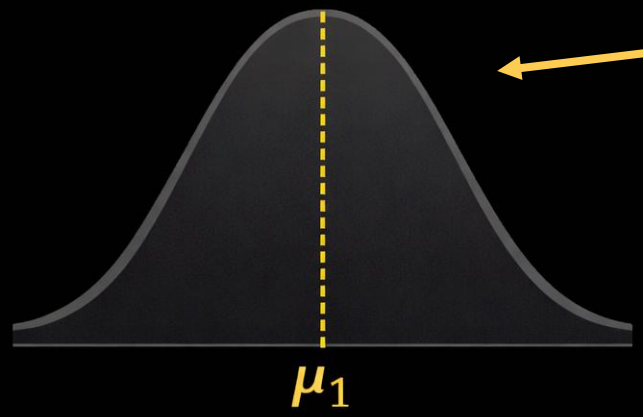
·Step 2: Specify null and alternative hypoth

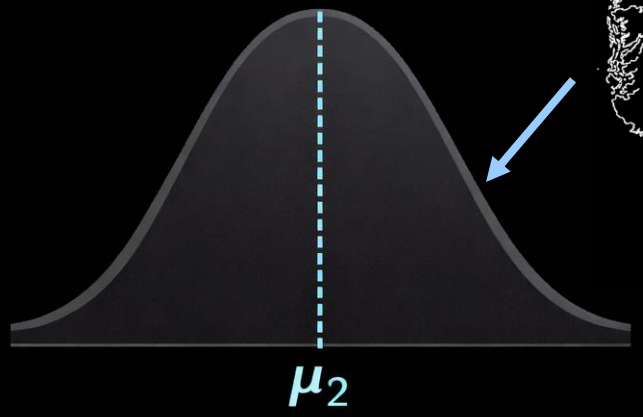
Energy nudge example:

$\mu_1 < \mu_2$?



Population 1: Households that receive a social comparison nudge

Mean electricity consumption: μ_1



Population 2: Households that do not receive a nudge

Mean electricity consumption: μ_2

•Step 2: Specify null and alternative hypotheses

Null-hypothesis (H_0): Describes what the population parameters would look like if your hypothesis is not supported.

Alternative hypothesis (H_A): Describes how population parameters would look if your original hypothesis is correct.

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•Step 2: Specify null and alternative hypotheses

No effect of nudging:

$$H_0: \mu_1 = \mu_2$$

An effect of nudging:

$$H_A: \mu_1 \neq \mu_2 \qquad \text{(two-sided/non-directional)}$$

$$H_A: \mu_1 < \mu_2 \qquad \text{(one-sided/directional)}$$

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•Step 2: Specify null and alternative hypotheses

Hypothesis: Social Comparison Nudge Reduces Electricity Consumption by more than 200 kWh

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•Step 2: Specify null and alternative hypotheses

No meaningful effect:

$$H_0: \mu_2 - \mu_1 \leq 200$$

Meaningful effect:

$$H_A: \mu_2 - \mu_1 > 200$$

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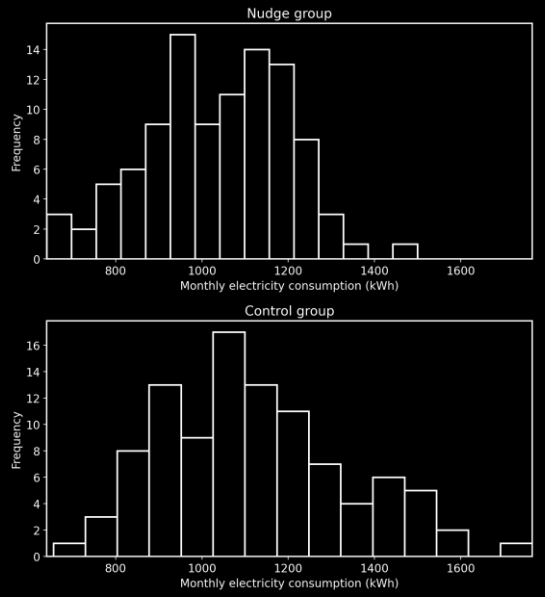
Step 3: Collect some data relevant to the hypothesis

1050 kWh ($\bar{X}_1$)

Nudge group
n = 100



Control group
n = 100

1125 kWh ($\bar{X}_2$)

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Step 4: Compute a test statistic

Null Hypothesis (H_0)

Observed Data

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Step 4: Compute a test statistic

Null Hypothesis (H_0)

$$H_0: \mu_1 - \mu_2 = 0$$

Observed Data

$$\bar{X}_1 - \bar{X}_2 = -75kwh$$

$$T = (\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2) = \quad -75kwh$$

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Step 4: Compute a test statistic

Null Hypothesis (H_0)

$$H_0: \mu_1 - \mu_2 = 0$$

Observed Data

$$\bar{X}_1 - \bar{X}_2 = -75kwh$$

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = -2.45$$

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A world where H_0 is true: The nudge has no effect

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A world where H_0 is true: The nudge has no effect

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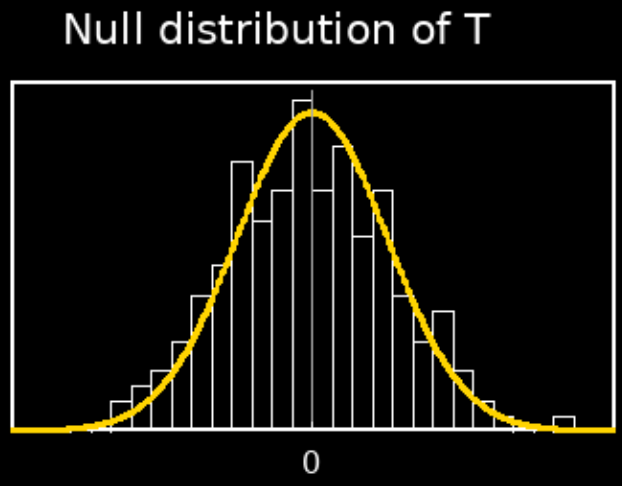

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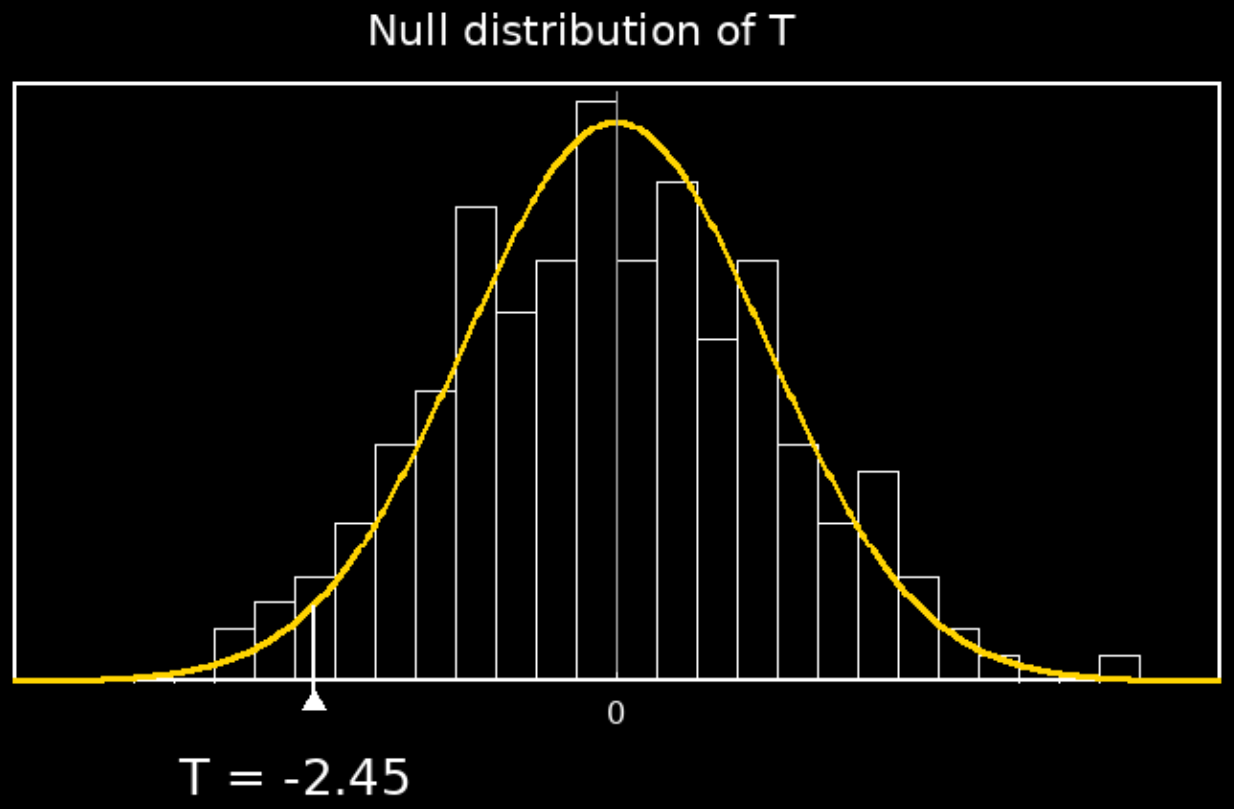

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Step 5: Determine the probability of the observed result under the null hypothesis

P-value: The probability of obtaining a test statistic as extreme as — or more extreme than — what we observed, under the assumption that the null hypothesis is true.

Null distribution: The distribution of the test statistic when the null hypothesis is true.

- **"Classical" methods**
- **Resampling and simulation methods**

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Classical methods

$$H_0: \mu_1 = \mu_2$$

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

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Classical methods

$$H_0: \mu_1 = \mu_2$$

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

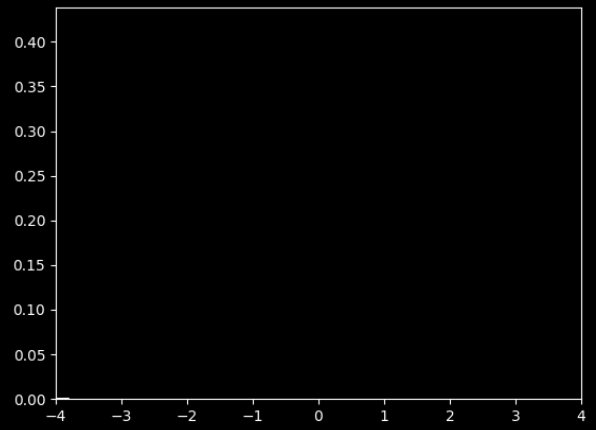
$$H_0: \sigma_1 = \sigma_2$$

$$F = S_1^2 / S_2^2$$

$$H_0: Indepedence$$

$$\chi^2 = \frac{\sum (o_i - e_i)^2}{e_i}$$

T-distribution



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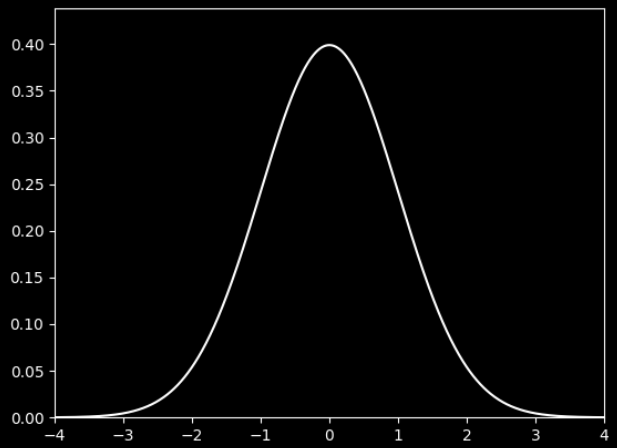
Classical methods

$$H_0: \mu_1 = \mu_2$$

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

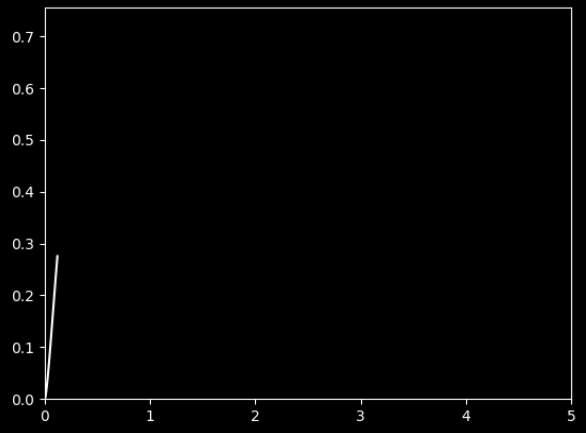
T-distribution



$$H_0: \sigma_1 = \sigma_2$$

$$F = S_1^2 / S_2^2$$

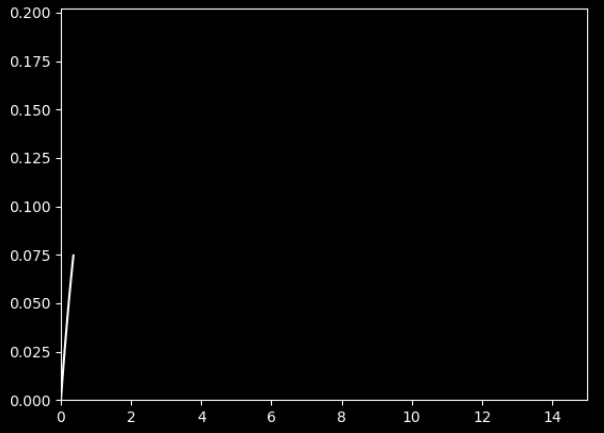
F-Distribution



$$H_0: Independence$$

$$\chi^2 = \frac{\sum (o_i - e_i)^2}{e_i}$$

Chi-squared distribution



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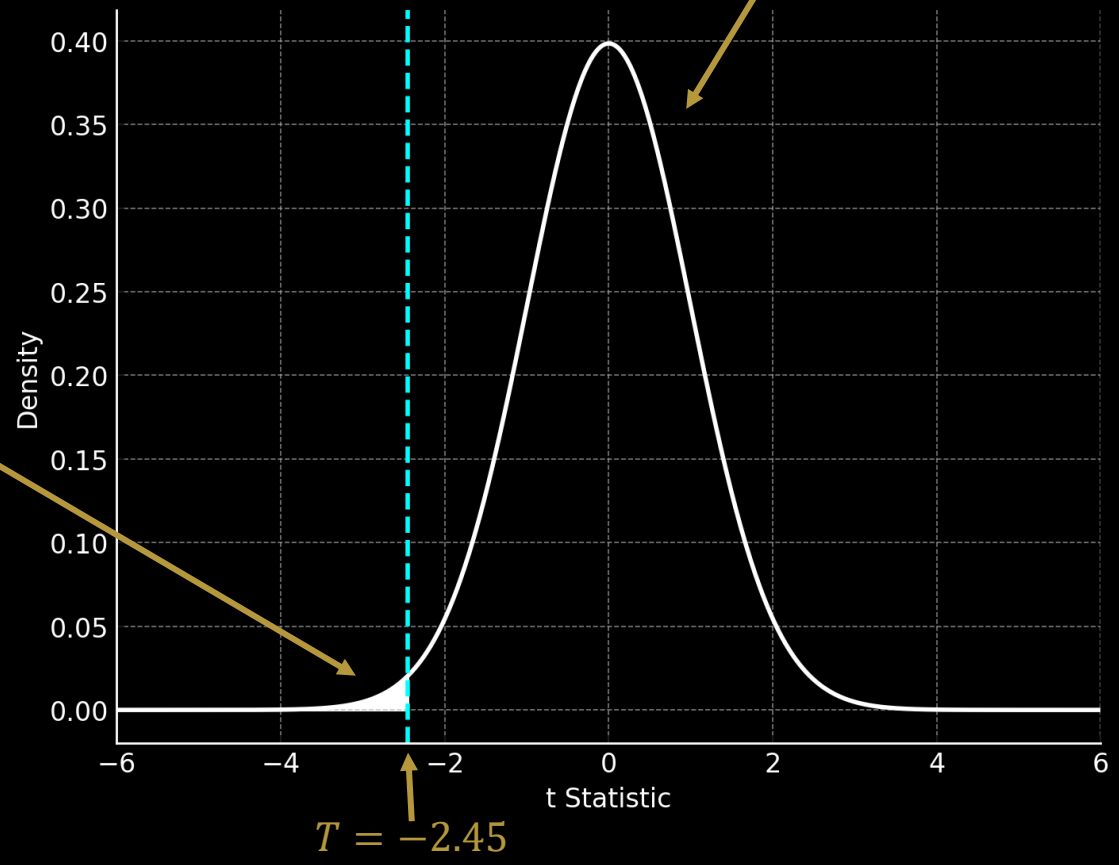
$t - distribution\ with\ 195\ degrees\ of\ freedom$

$P - value = P(T \leq -2.45|H_0) \approx 0.008$



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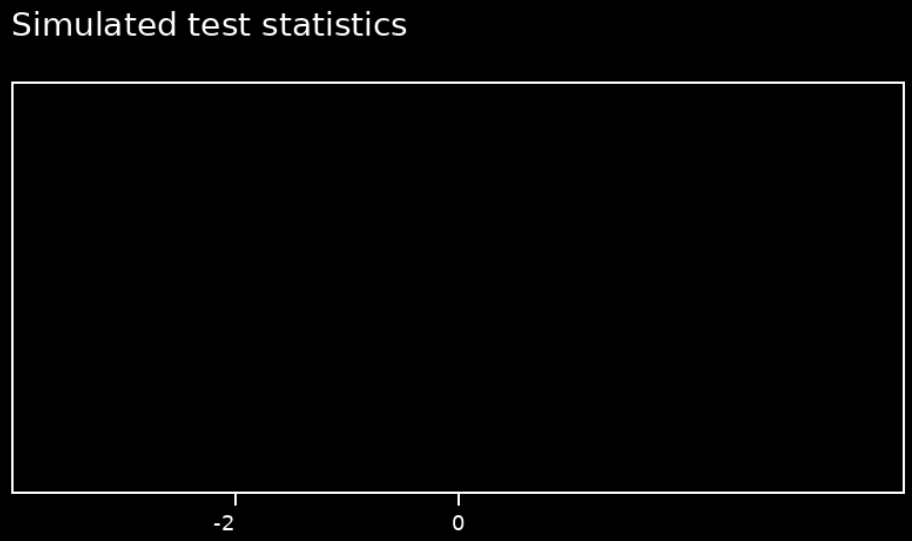
Resampling/simulation method:

- We **simulate/resample data** from a world where the null hypothesis is true many times.
- Each new dataset produces **a new test statistic**.
- The **proportion** of test statistics **more extreme** than our observed value gives us a **p-value**



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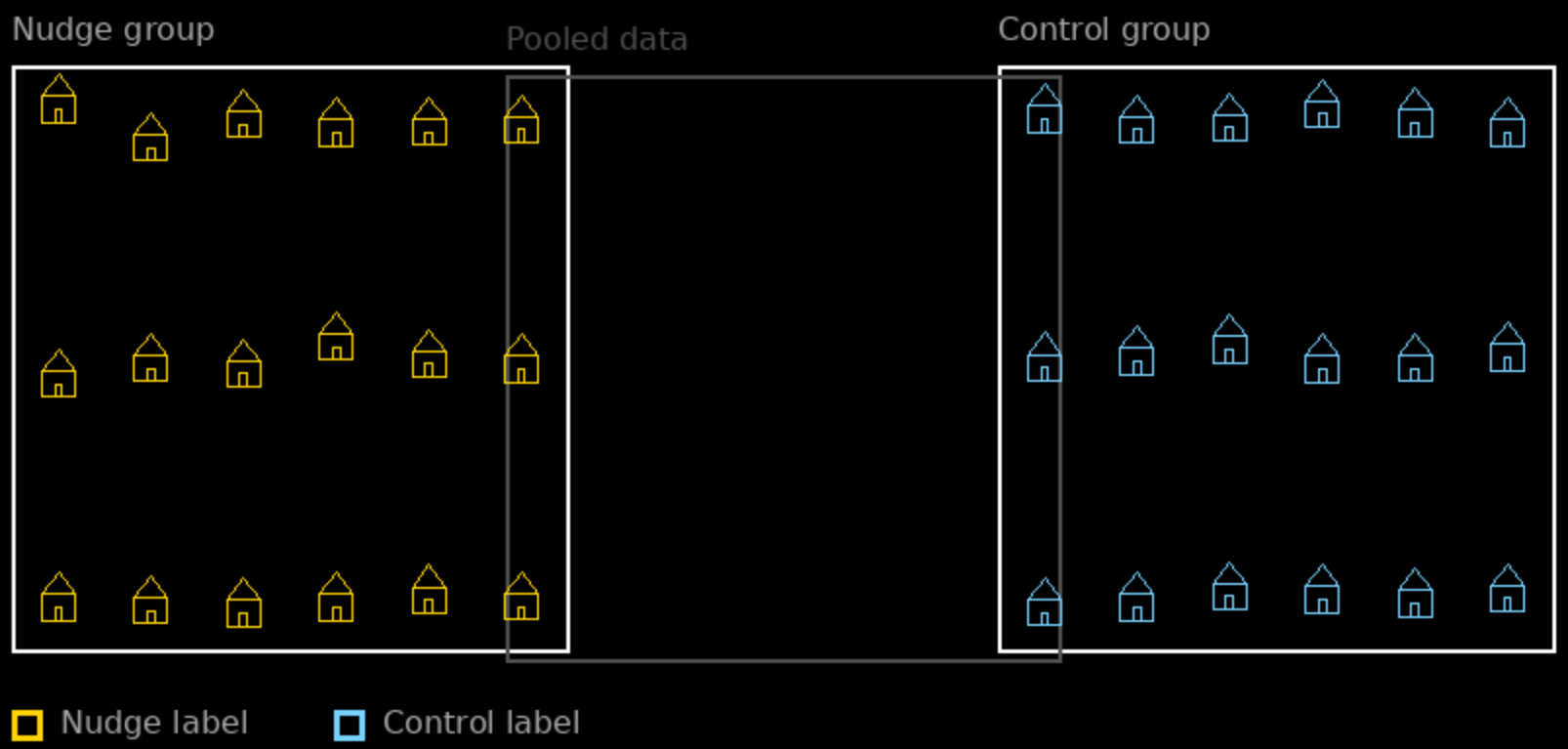
Nudge group
Pooled data
Control group
Nudge label
Control label

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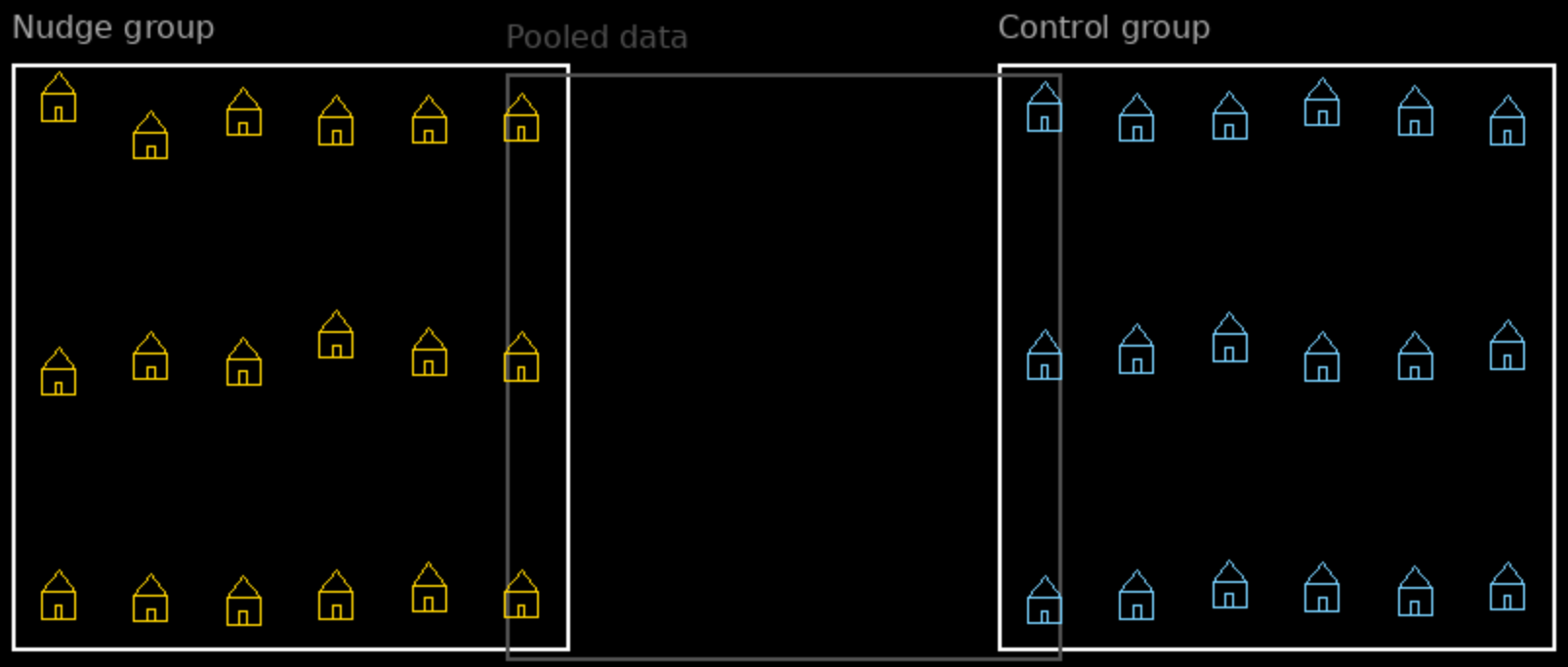

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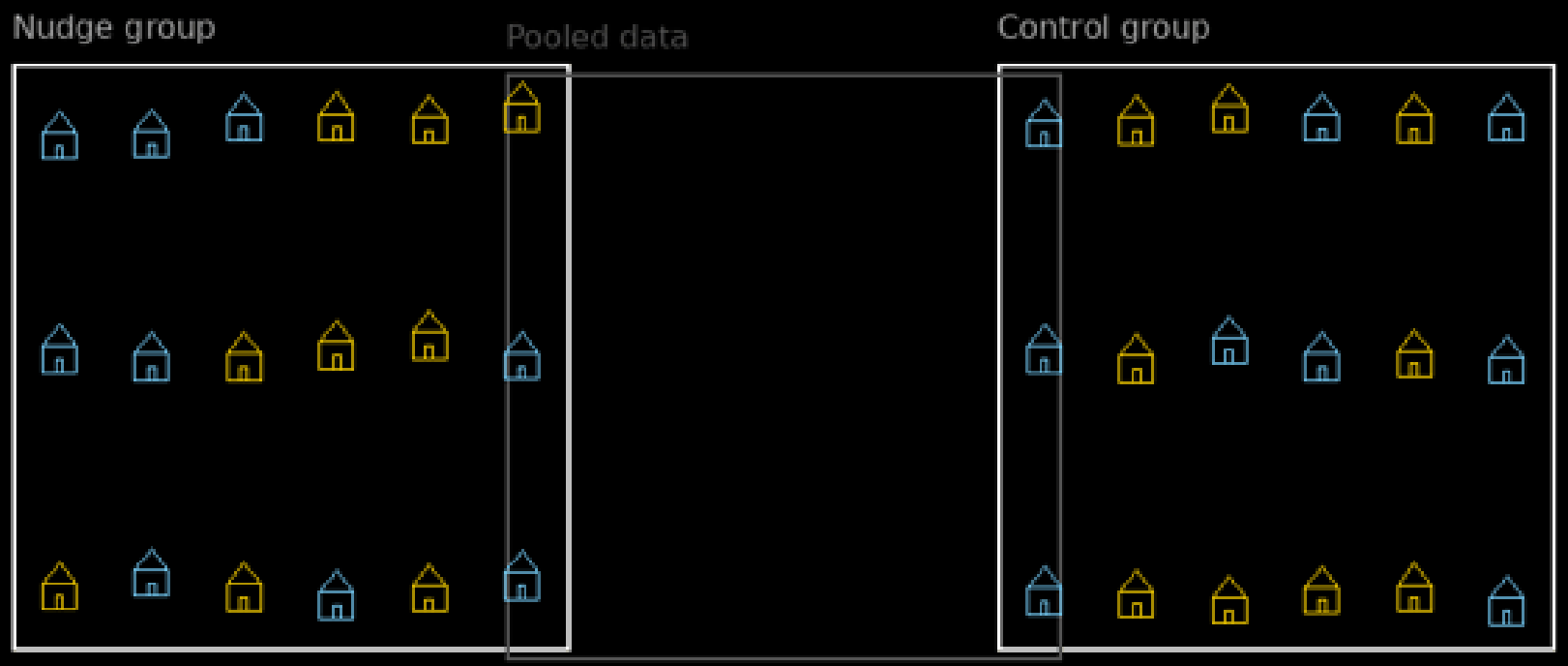

T = -0.14

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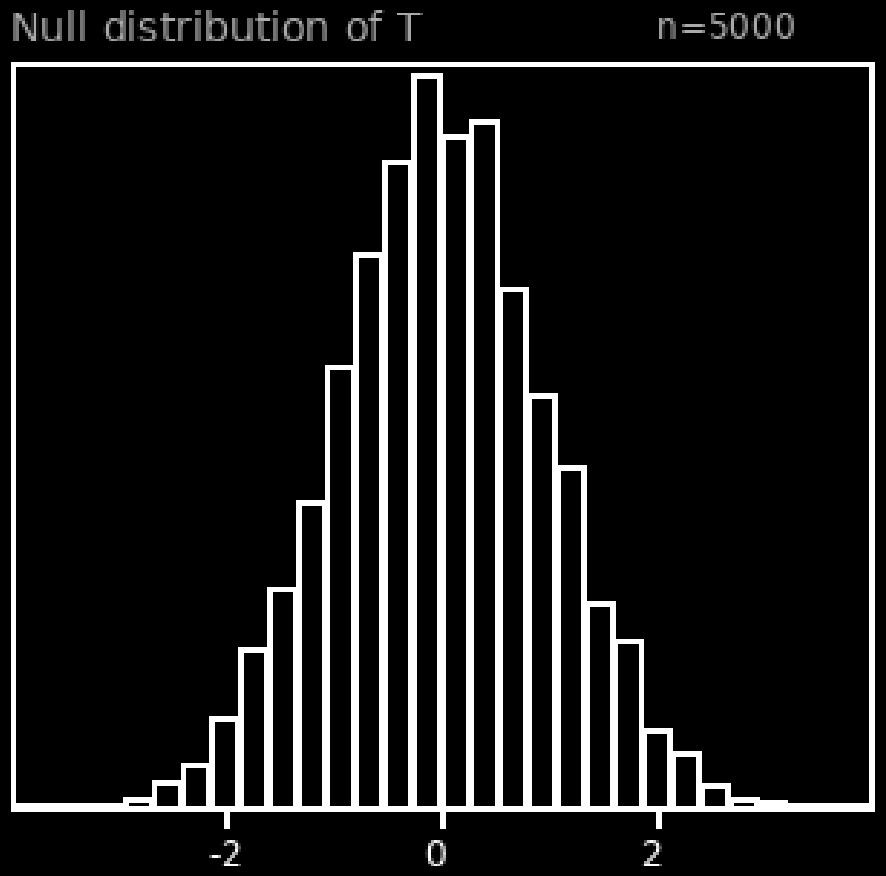

$T = -2.45$

$$P - value \approx \frac{\#\ statistics < -2.45}{5000} = 0.0076$$

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Step 6: Assess the "statistical significance" of the result

$$P - value = 0.0076 \overset{?}{\leq} \alpha$$

Significance level

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Step 6: Assess the "statistical significance" of the result

$$P - value = 0.0076 \leq 0.01$$

$$\rightarrow Reject\ H_0$$

→ There is statistical significant evidence that the nudge reduce electricity consumption

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The Logic of NHST

1. **Formulate a hypothesis** that embodies our prediction (before seeing the data)
2. Specify **null and alternative hypotheses**
3. Collect some **data** relevant to the hypothesis
4. Compute a **statistic** that can quantify the amount of evidence against the null hypothesis
5. Compute the **probability of** the observed value (or something more "extreme") of that **statistic** assuming that the **null hypothesis is true**
6. Assess the "**statistical significance**" of the result

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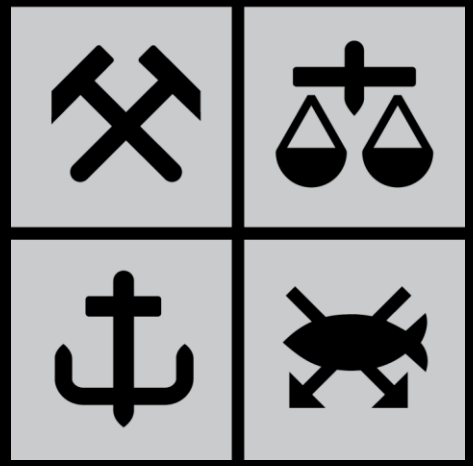

Sondre Hølleland
Geir Drage Berentsen