In-vehicle battery durability for electrified vehicles

PART A: Verification of monitors
Option B

Web meeting

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Proposal

- Extending CO_2 CoP vehicle selection procedure for verification of battery monitors
- The goal of the method is to use a robust statistical method, which would allow verifying the SOCR/SOCE monitors for the battery, according to the following requirements:
  - Basing the pass or fail criterion for a family on sound statistical criteria
  - Making a decision only if sufficient confidence is reached and evidence is taken into account
  - Reaching a conclusion with the least amount of tested vehicles possible, in order to minimize the cost
  - Reaching the best compromise possible between the OEM's and the costumer's risk
- The method is a sequential sampling approach based on constructing confidence intervals
- The central idea is to define the pass and fail boundaries for each step (per each number of vehicles tested), in such a way that the required confidence level (CL) will have to be met in order to reach a decision

Verifying the method for the battery monitors

- For evaluating the SOCR/SOCE monitors normalised values shall be calculated:

$$x_i = \frac{SOC_{read,i}}{SOC_{measured,i}} \quad \text{or} \quad x_i = SOC_{read,i} - SOC_{measured,i}$$

- Where: $SOC_{read,i}$ is the SOCR/SOCE monitor read from the vehicle i

  $SOC_{measured,i}$ is the measured SOCR/SOCE monitor of the vehicle i

- For the total number of N tests and the normalised values of the tested vehicles, x_1, x_2, … x_N, the **average** X_{tests} and the **standard deviation** s shall be determined:

$$X_{tests} = \frac{(x_1+x_2+x_3+\cdots+x_N)}{N}$$

$$s = \sqrt{\frac{(x_1 - X_{tests})^2 + (x_2 - X_{tests})^2 + \ldots + (x_N - X_{tests})^2}{N-1}}$$

Summary of the methodology

- The proposed testing method follows the same steps of CO_2 CoP testing:
  - Boundaries around a theoretical mean

$$m(i) = A - t_{N-1,cL} * \frac{s(i)}{\sqrt{N}}$$

$$lb(i) = \mathrm{m(i)} - t_{i-1,cL} * \frac{s(i)}{\sqrt{i}} = A - \left(\frac{t_{i-1,Cl(i)}}{\sqrt{i}} + \frac{t_{N-1,Cl(i)}}{\sqrt{N}}\right) * s(i)$$

$$ub(i) = \mathrm{m(i)} + t_{i-1,cL} * \frac{s(i)}{\sqrt{i}} = A + \left(\frac{t_{i-1,Cl(i)}}{\sqrt{i}} - \frac{t_{N-1,Cl(i)}}{\sqrt{N}}\right) * s(i)$$

  - If $Xtests \leq A - (t_{P1,N} + t_{P2,N}) \cdot s$ the family gets a pass
  - If $Xtests > A + (t_{F1,N} - t_{F2,N}) \cdot s$ the family gets a fail
  - Else it is required to measure another vehicle, increase N by 1, recalculate the mean and the standard deviation and repeat until a decision of pass or fail is reached

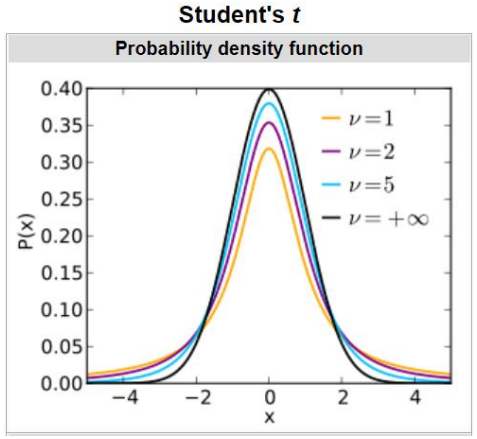
  - Fail boundary with constant confidence level (same as CO_2 CoP)

```
cL_up = 0.95;
```

  - Pass boundary with decreasing confidence level (same as CO_2 CoP) while i increases

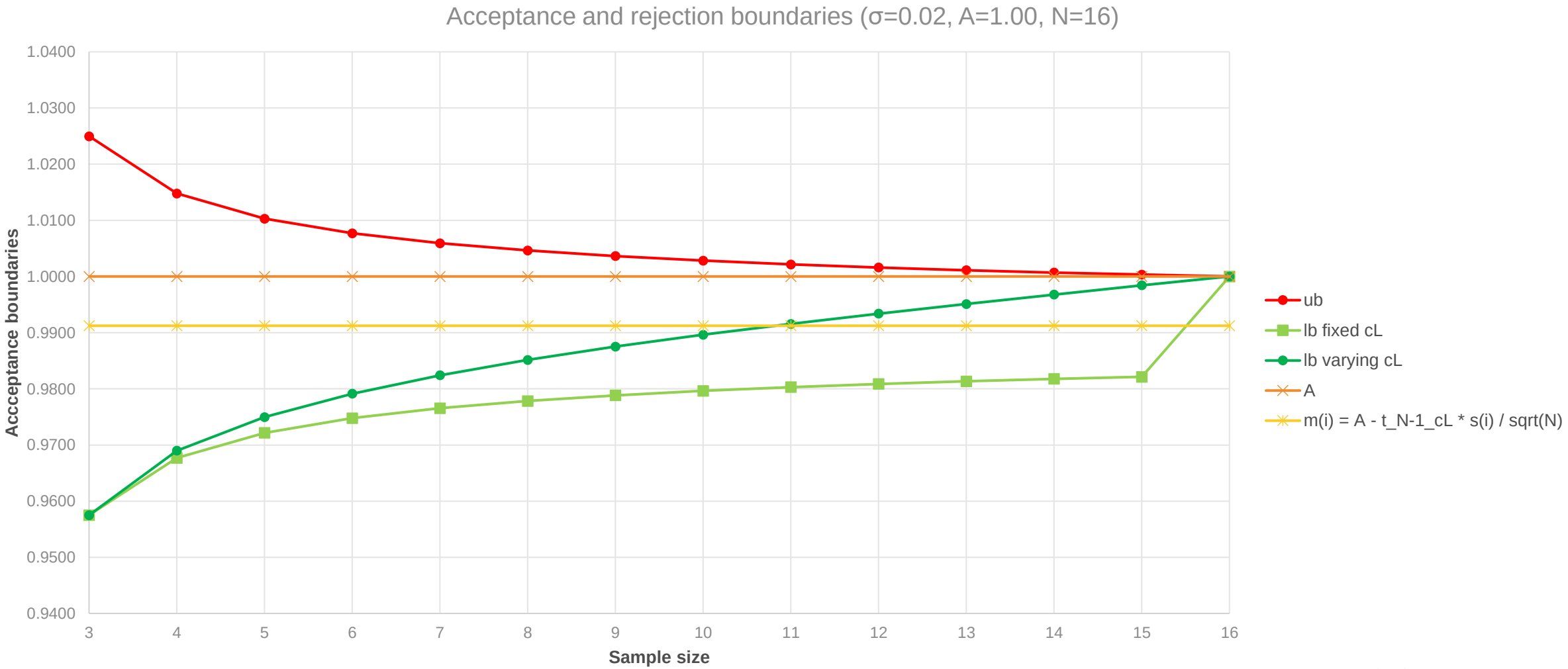
```
cL_lo = [0.95 0.945 0.935 0.92 0.9  0.875 0.845 0.81 0.77 0.725 0.675 0.62 0.56 0.5];
```

Confidence level decrement increasing proportionally with sample size



	PASS		FAIL	
Tests (i)	$t_{P1,i}$	$t_{P2,i}$	$t_{F1,i}$	t_{F2}
3	1.686	0.438	1.686	0.438
4	1.125	0.425	1.177	0.438
5	0.850	0.401	0.953	0.438
6	0.673	0.370	0.823	0.438
7	0.544	0.335	0.734	0.438
8	0.443	0.299	0.670	0.438
9	0.361	0.263	0.620	0.438
10	0.292	0.226	0.580	0.438
11	0.232	0.190	0.546	0.438
12	0.178	0.153	0.518	0.438
13	0.129	0.116	0.494	0.438
14	0.083	0.078	0.473	0.438
15	0.040	0.038	0.455	0.438
16	0.000	0.000	0.438	0.438

Example of the proposed method



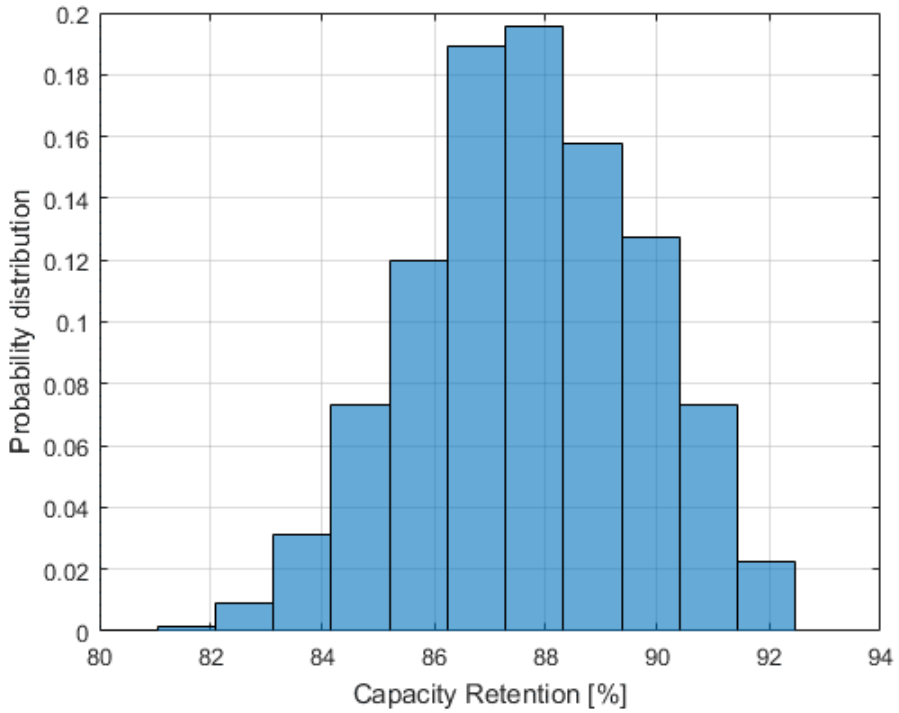
Applying the proposed method to battery monitors

- Ideally we should have couples of read and measured data; on this stage only possible to sample the data from defined generated distributions.
- Three options were followed:
  - JRC TEMA capacity retention distribution at 5y - aged BEV1 vehicles – strategy 1 and 2
  - JRC TEMA capacity retention distribution at 8y - aged BEV1 vehicles – strategy 1 and 2
  - Normal distribution 10’000 values randomly generated (m = 80; std = 1,56)
- Matlab code was used for iteration and statistics generation of pass/fail results

Datasets

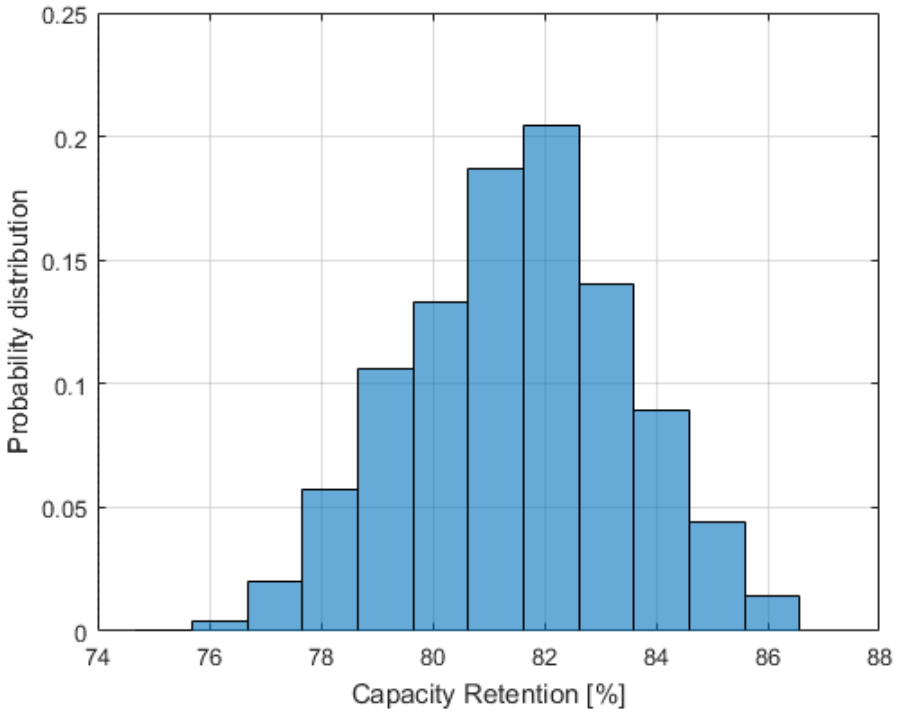
- JRC TEMA simulated data distributions (ref. EVE-41-03e)

5y aged BEV1 vehicles – strategy 1 and 2



min	1st Qu	median	mean	3rd Qu	max	sd
80.168	86.319	87.675	87.694	89.155	92.437	2.002

8y aged BEV1 vehicles – strategy 1 and 2



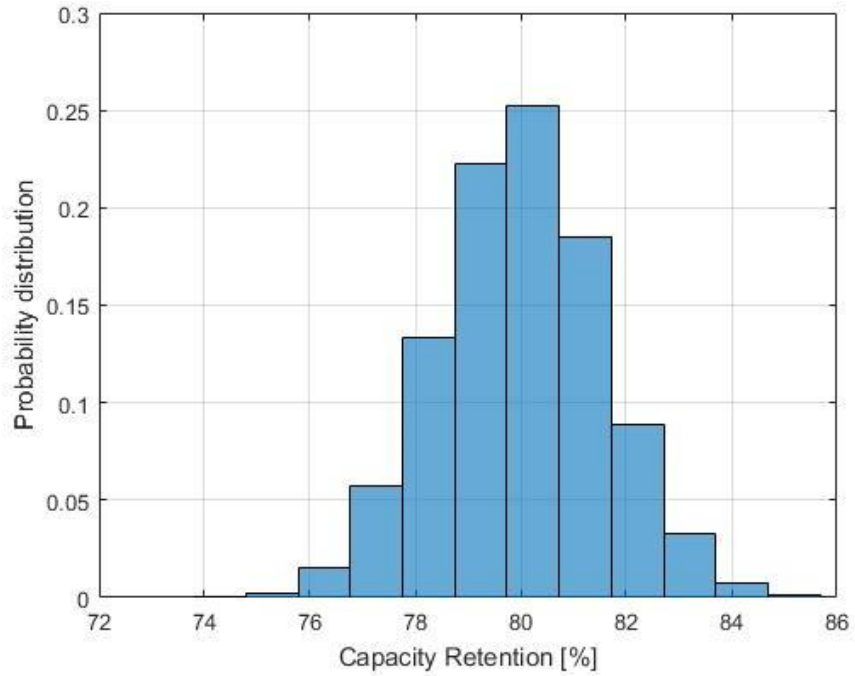
min	1st Qu	median	mean	3rd Qu	max	sd
74.774	80.155	81.597	81.511	82.831	86.495	1.959

Datasets

- In accordance with OICA simulations: Randomly generated normal distribution 10’000 values (μ = 80; σ = 1,56)

```
Data = normrnd(80,1.56,[10000,1]);
```

Example of randomly generated normal distribution



min	1st Qu	median	mean	3rd Qu	max	sd
74.162	78.9719	80.0135	80.002	81.0250	85.5823	1.5467

1. Verifying the method with TEMA data

- Assumptions:
  - $SOC_{measured}$ from JRC TEMA simulation of capacity retention
    - Simulated data of capacity retention
    - Samples coming from a single population of simulated data (at 5y or 8y)
    - $SOC_{measured}$ sampled randomly from population with iteration procedure to get pass/fail percentages, 16 vehicles each iterations
  - SOC_{read} assumed values, **constant** within the same vehicle family

- Outcomes:
  - 2000 iterations to generate statistics
  - Preliminary statistics depending on soc_{read} value chosen (below / above mean value of population)
  - Parameter A to be verified
  - Effect of outliers

Effect of number of iterations on computed statistics

- A=1; SOC_{read} = 86; RATIO; 5y

2000 iterations

n° iterations	1000		1500		2000		2500		3000		3500		5000	
Sample size	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate
3	20.5%	0.4%	18.6%	0.3%	18.3%	0.4%	17.4%	0.6%	18.2%	0.7%	17.4%	0.5%	19.3%	0.5%
4	11.5%	0.5%	10.9%	0.3%	10.6%	0.4%	10.7%	0.2%	10.2%	0.2%	10.8%	0.3%	10.5%	0.2%
Cumulative	32.0%	0.9%	29.5%	0.6%	28.8%	0.7%	28.1%	0.9%	28.4%	0.9%	28.2%	0.7%	29.8%	0.8%
5	10.7%	0.1%	9.7%	0.0%	10.4%	0.3%	9.1%	0.2%	9.2%	0.3%	9.8%	0.3%	9.8%	0.1%
6	9.1%	0.0%	9.8%	0.2%	10.0%	0.2%	9.4%	0.1%	9.4%	0.1%	9.6%	0.1%	9.1%	0.0%
7	10.3%	0.0%	8.6%	0.1%	9.7%	0.1%	10.1%	0.0%	10.2%	0.0%	10.0%	0.1%	9.6%	0.0%
8	9.6%	0.1%	11.0%	0.1%	10.2%	0.1%	9.9%	0.0%	10.2%	0.0%	10.3%	0.1%	9.9%	0.0%
Cumulative	71.7%	1.1%	68.6%	0.9%	69.1%	1.3%	66.6%	1.3%	67.4%	1.3%	67.9%	1.3%	68.2%	1.0%
9	8.1%	0.0%	9.2%	0.0%	9.8%	0.0%	10.8%	0.0%	9.9%	0.0%	10.3%	0.0%	9.5%	0.0%
10	8.1%	0.0%	9.1%	0.0%	7.6%	0.0%	8.4%	0.0%	8.7%	0.0%	8.3%	0.0%	8.8%	0.0%
11	4.7%	0.1%	5.1%	0.0%	5.2%	0.0%	6.3%	0.0%	5.9%	0.0%	5.7%	0.0%	5.6%	0.0%
12	3.5%	0.1%	3.7%	0.0%	3.7%	0.0%	3.4%	0.0%	3.5%	0.0%	3.4%	0.0%	3.8%	0.0%
Cumulative	96.1%	1.3%	95.7%	0.9%	95.3%	1.3%	95.6%	1.4%	95.4%	1.3%	95.5%	1.3%	95.9%	1.1%
13	1.4%	0.0%	2.0%	0.1%	2.3%	0.0%	2.1%	0.0%	1.9%	0.0%	2.1%	0.0%	1.9%	0.0%
14	0.9%	0.0%	0.9%	0.0%	0.7%	0.0%	0.6%	0.1%	0.9%	0.0%	0.6%	0.1%	0.8%	0.0%
15	0.2%	0.0%	0.2%	0.0%	0.4%	0.1%	0.1%	0.0%	0.2%	0.0%	0.2%	0.0%	0.3%	0.0%
16	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
Cumulative	98.7%	1.3%	98.9%	1.1%	98.7%	1.4%	98.5%	1.5%	98.6%	1.4%	98.5%	1.5%	98.9%	1.1%

	1000		1500		2000		2500		3000		3500		5000	
Cumulative	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate
4	32.0%	0.9%	29.5%	0.6%	28.8%	0.7%	28.1%	0.9%	28.4%	0.9%	28.2%	0.7%	29.8%	0.8%
8	71.7%	1.1%	68.6%	0.9%	69.1%	1.3%	66.6%	1.3%	67.4%	1.3%	67.9%	1.3%	68.2%	1.0%
12	96.1%	1.3%	95.7%	0.9%	95.3%	1.3%	95.6%	1.4%	95.4%	1.3%	95.5%	1.3%	95.9%	1.1%
16	98.7%	1.3%	98.9%	1.1%	98.7%	1.4%	98.5%	1.5%	98.6%	1.4%	98.5%	1.5%	98.9%	1.1%

Varying of SOC_{read} to understand its influence on pass/fail percentage

- A=1; 2000 repetitions; RATIO; 5y
- Varying SOC_{read}

socRead	80		81		82		83		84		85		86		87		87.6937		88		89		90	
Sample size	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate
3	97.0%	0.0%	92.4%	0.0%	82.6%	0.0%	68.6%	0.0%	52.9%	0.0%	35.6%	0.0%	19.3%	0.4%	8.4%	3.1%	3.7%	7.9%	2.5%	12.0%	0.6%	26.4%	0.2%	48.0%
4	2.9%	0.0%	7.2%	0.0%	15.0%	0.0%	21.1%	0.0%	22.6%	0.0%	17.9%	0.1%	9.6%	0.1%	3.0%	2.2%	0.9%	6.3%	0.7%	9.2%	0.1%	21.7%	0.0%	32.0%
Cumulative	99.9%	0.0%	99.5%	0.0%	97.6%	0.0%	89.7%	0.0%	75.5%	0.0%	53.4%	0.1%	28.8%	0.5%	11.4%	5.3%	4.6%	14.1%	3.2%	21.1%	0.7%	48.1%	0.2%	79.9%
5	0.2%	0.0%	0.5%	0.0%	2.3%	0.0%	8.7%	0.0%	13.8%	0.0%	15.3%	0.0%	9.5%	0.1%	3.6%	1.7%	0.8%	6.8%	0.9%	9.2%	0.1%	17.5%	0.0%	13.8%
6	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	1.4%	0.0%	7.2%	0.0%	12.4%	0.0%	9.9%	0.1%	3.4%	1.9%	0.9%	5.4%	0.4%	8.5%	0.2%	12.3%	0.0%	4.4%
7	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.3%	0.0%	2.7%	0.0%	9.8%	0.0%	11.9%	0.1%	3.6%	1.4%	1.2%	5.9%	0.5%	7.4%	0.1%	7.7%	0.0%	1.3%
8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	5.2%	0.0%	9.7%	0.1%	5.1%	1.4%	0.8%	4.5%	0.7%	7.0%	0.1%	5.9%	0.0%	0.4%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	99.7%	0.0%	96.1%	0.1%	69.6%	0.8%	26.9%	11.6%	8.2%	36.6%	5.6%	53.1%	1.0%	91.4%	0.2%	99.8%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	2.6%	0.0%	8.9%	0.0%	6.1%	0.9%	1.8%	5.2%	0.6%	4.8%	0.0%	3.3%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.8%	0.0%	9.1%	0.1%	6.5%	1.3%	2.0%	4.4%	1.0%	5.3%	0.0%	1.8%	0.0%	0.1%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	5.2%	0.0%	7.7%	1.3%	2.2%	3.7%	1.2%	4.0%	0.0%	1.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.8%	0.0%	9.2%	1.1%	4.2%	2.8%	1.2%	3.6%	0.0%	0.8%	0.0%	0.1%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.1%	96.5%	0.9%	56.3%	16.1%	18.3%	52.6%	9.6%	70.8%	1.0%	98.1%	0.2%	99.9%
13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	9.2%	1.1%	4.5%	2.7%	2.0%	3.5%	0.0%	0.3%	0.0%	0.0%
14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	7.6%	0.8%	5.1%	3.2%	3.2%	2.8%	0.1%	0.4%	0.0%	0.0%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	5.9%	0.6%	6.1%	2.6%	2.7%	2.1%	0.1%	0.1%	0.0%	0.0%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	2.0%	0.7%	3.3%	1.8%	2.1%	1.4%	0.1%	0.0%	0.0%	0.0%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.1%	99.2%	0.9%	80.9%	19.2%	37.2%	62.8%	19.5%	80.5%	1.2%	98.8%	0.2%	99.9%

Varying of SOC_{read} to understand its influence on pass/fail percentage

- A=1,01; 2000 repetitions; RATIO; 5y
- Varying SOC_{read}

socRead	80		81		82		83		84		85		86		87		87.6937		88		89		90	
Sample size	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate
3	98.7%	0.0%	95.6%	0.0%	90.3%	0.0%	79.3%	0.0%	68.1%	0.0%	49.3%	0.0%	31.3%	0.1%	16.4%	1.0%	9.8%	2.1%	7.7%	4.2%	1.9%	12.9%	0.5%	30.3%
4	1.3%	0.0%	4.3%	0.0%	9.1%	0.0%	17.1%	0.0%	21.3%	0.0%	21.8%	0.0%	17.3%	0.0%	9.2%	0.2%	5.1%	1.4%	3.5%	2.8%	0.6%	10.6%	0.1%	22.8%
Cumulative	100.0%	0.0%	99.9%	0.0%	99.4%	0.0%	96.4%	0.0%	89.3%	0.0%	71.1%	0.0%	48.6%	0.1%	25.6%	1.2%	14.8%	3.5%	11.2%	6.9%	2.4%	23.5%	0.5%	53.1%
5	0.0%	0.0%	0.2%	0.0%	0.6%	0.0%	3.5%	0.0%	8.4%	0.0%	15.3%	0.0%	14.2%	0.0%	8.8%	0.3%	4.3%	2.0%	2.1%	2.1%	0.4%	10.4%	0.1%	18.5%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	1.9%	0.0%	7.9%	0.0%	12.4%	0.0%	8.0%	0.0%	4.4%	0.6%	2.5%	2.3%	0.4%	9.3%	0.0%	11.0%
7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.4%	0.0%	4.0%	0.0%	11.1%	0.1%	9.2%	0.1%	5.0%	0.6%	3.8%	2.7%	0.3%	8.6%	0.1%	7.5%
8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	1.4%	0.0%	6.9%	0.0%	9.4%	0.1%	5.9%	0.9%	3.6%	2.2%	0.3%	7.1%	0.0%	4.3%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	99.5%	0.0%	93.0%	0.1%	61.0%	1.7%	34.3%	7.5%	23.0%	16.1%	3.8%	58.8%	0.7%	94.4%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	4.5%	0.0%	9.5%	0.1%	6.3%	1.1%	4.3%	1.8%	0.5%	6.5%	0.0%	1.9%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	1.5%	0.0%	10.5%	0.1%	8.7%	0.7%	6.5%	2.1%	0.6%	5.6%	0.0%	1.6%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	7.3%	0.1%	8.2%	0.7%	6.7%	1.9%	0.5%	4.1%	0.0%	0.6%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	4.1%	0.0%	8.9%	0.6%	7.8%	1.3%	1.1%	3.8%	0.0%	0.4%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	99.9%	0.1%	92.4%	1.9%	66.3%	10.5%	48.2%	23.2%	6.4%	78.7%	0.7%	98.8%
13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.4%	0.0%	9.1%	0.6%	7.7%	1.3%	1.7%	2.4%	0.0%	0.3%
14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	6.0%	0.2%	8.4%	1.2%	1.7%	2.6%	0.0%	0.1%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	5.1%	0.8%	5.7%	1.0%	2.1%	2.0%	0.1%	0.1%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	1.4%	0.2%	2.5%	1.0%	1.7%	1.1%	0.0%	0.1%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	99.9%	0.1%	98.0%	2.0%	87.8%	12.2%	72.4%	27.6%	13.4%	86.6%	0.7%	99.3%

Effect of outliers

- A=1; SOC_{read} = 86; 2000 repetitions; RATIO; 5y - Simulated outlier at 1st or 5th sampled car
- The 1st or 5th sampled value of $soc_{measured}$ is reduced by 30%, 20%, 10% to simulate an outlier

socRead = 86	sample(1) x 0.7		sample(1) x 0.8		sample(1) x 0.9	
Sample size	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate
3	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
4	0.0%	0.0%	0.0%	0.2%	0.0%	0.8%
Cumulative	0.0%	0.0%	0.0%	0.2%	0.0%	1.0%
5	0.0%	0.3%	0.0%	1.1%	0.0%	1.3%
6	0.0%	6.6%	0.0%	3.4%	0.0%	0.9%
7	0.0%	17.6%	0.0%	5.5%	0.0%	1.4%
8	0.0%	20.9%	0.0%	5.9%	0.3%	0.9%
Cumulative	0.0%	45.3%	0.0%	16.0%	0.3%	5.5%
9	0.0%	16.2%	0.0%	5.8%	1.8%	0.9%
10	0.0%	11.2%	0.0%	5.2%	5.0%	0.6%
11	0.0%	7.5%	0.0%	4.1%	9.2%	0.6%
12	0.0%	4.9%	0.0%	2.9%	18.4%	0.4%
Cumulative	0.0%	85.0%	0.0%	33.9%	34.5%	7.8%
13	0.0%	3.5%	0.6%	2.9%	21.7%	0.5%
14	0.0%	2.6%	5.2%	1.7%	21.2%	0.2%
15	0.2%	1.3%	24.1%	2.3%	11.6%	0.2%
16	6.8%	0.8%	28.2%	1.4%	2.4%	0.1%
Cumulative	7.0%	93.1%	58.0%	42.1%	91.3%	8.7%

socRead = 86	sample(5) x 0.7		sample(5) x 0.8		sample(5) x 0.9	
Sample size	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate
3	19.1%	0.6%	18.8%	0.6%	17.2%	0.7%
4	9.9%	0.2%	11.5%	0.2%	11.0%	0.5%
Cumulative	29.0%	0.8%	30.3%	0.8%	28.2%	1.2%
5	0.0%	0.2%	0.0%	0.5%	0.0%	1.1%
6	0.0%	5.7%	0.0%	2.7%	0.0%	1.5%
7	0.0%	15.4%	0.0%	5.1%	0.0%	1.5%
8	0.0%	16.9%	0.0%	5.3%	0.0%	0.9%
Cumulative	29.0%	38.9%	30.3%	14.2%	28.2%	6.0%
9	0.0%	11.5%	0.0%	4.8%	0.7%	0.8%
10	0.0%	7.7%	0.0%	4.5%	2.3%	0.6%
11	0.0%	3.6%	0.0%	3.3%	5.5%	0.4%
12	0.0%	2.2%	0.0%	2.1%	11.4%	0.3%
Cumulative	29.0%	63.7%	30.3%	28.8%	48.0%	8.0%
13	0.0%	1.9%	0.1%	1.8%	16.5%	0.2%
14	0.0%	1.2%	2.5%	1.7%	15.6%	0.3%
15	0.0%	0.6%	15.1%	1.0%	8.7%	0.2%
16	3.2%	0.6%	17.9%	1.2%	2.6%	0.2%
Cumulative	32.2%	67.9%	65.8%	34.3%	91.2%	8.8%

Varying of SOC_{read} to understand its influence on pass/fail percentage

- A=1; 2000 repetitions; 8y
- Varying SOC_{read}

socRead	75		76		77		78		79		80		81		81.5105		82		83		84		85	
Sample size	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate	Pass Rate	Fail Rate
3	90.6%	0.0%	81.8%	0.0%	67.5%	0.0%	49.5%	0.0%	34.7%	0.2%	19.0%	0.9%	7.0%	3.6%	3.7%	7.7%	1.8%	13.6%	0.5%	33.4%	0.0%	56.0%	0.0%	77.7%
4	8.9%	0.0%	16.1%	0.0%	22.7%	0.0%	22.0%	0.0%	17.0%	0.0%	8.9%	0.4%	3.6%	2.6%	1.3%	7.4%	0.4%	13.0%	0.1%	24.2%	0.0%	30.2%	0.0%	20.5%
Cumulative	99.5%	0.0%	97.9%	0.0%	90.1%	0.0%	71.5%	0.0%	51.7%	0.2%	27.9%	1.3%	10.6%	6.2%	5.0%	15.0%	2.2%	26.6%	0.5%	57.6%	0.0%	86.2%	0.0%	98.1%
5	0.5%	0.0%	2.1%	0.0%	7.8%	0.0%	15.5%	0.0%	14.0%	0.0%	7.7%	0.1%	3.1%	3.6%	1.1%	6.3%	0.2%	10.8%	0.0%	16.8%	0.0%	10.3%	0.0%	1.8%
6	0.0%	0.0%	0.1%	0.0%	2.0%	0.0%	8.6%	0.0%	12.4%	0.0%	8.7%	0.2%	2.7%	2.5%	1.2%	5.9%	0.3%	9.2%	0.0%	10.5%	0.0%	2.4%	0.0%	0.1%
7	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	3.4%	0.0%	9.7%	0.0%	8.2%	0.1%	2.7%	2.4%	0.9%	5.3%	0.4%	9.1%	0.0%	6.3%	0.0%	0.9%	0.0%	0.0%
8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	6.3%	0.0%	9.1%	0.3%	3.2%	2.3%	0.9%	5.0%	0.2%	7.6%	0.0%	4.0%	0.0%	0.2%	0.0%	0.0%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	99.9%	0.0%	94.0%	0.2%	61.5%	1.9%	22.2%	16.9%	8.9%	37.4%	3.3%	63.2%	0.5%	95.1%	0.0%	100.0%	0.0%	100.0%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	3.6%	0.0%	8.1%	0.1%	3.7%	1.7%	1.3%	4.6%	0.4%	6.1%	0.1%	2.0%	0.0%	0.0%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%	9.8%	0.2%	5.1%	1.7%	2.0%	4.3%	0.5%	5.3%	0.0%	0.9%	0.0%	0.1%	0.0%	0.0%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	8.4%	0.0%	7.2%	1.2%	2.5%	3.4%	0.6%	3.4%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	4.7%	0.1%	8.4%	1.6%	3.0%	4.5%	0.8%	3.5%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	99.8%	0.2%	92.4%	2.2%	46.5%	23.0%	17.6%	54.1%	5.4%	81.4%	0.6%	98.9%	0.0%	100.0%	0.0%	100.0%
13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	3.6%	0.0%	9.2%	1.7%	5.1%	3.1%	0.8%	2.8%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.1%	8.1%	1.1%	5.8%	2.3%	1.6%	2.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.1%	6.4%	0.8%	5.4%	2.3%	2.3%	1.3%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	2.8%	0.7%	3.1%	1.5%	1.3%	1.2%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%
Cumulative	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	99.9%	0.2%	97.7%	2.3%	72.9%	27.2%	36.9%	63.1%	11.3%	88.7%	0.6%	99.4%	0.0%	100.0%	0.0%	100.0%

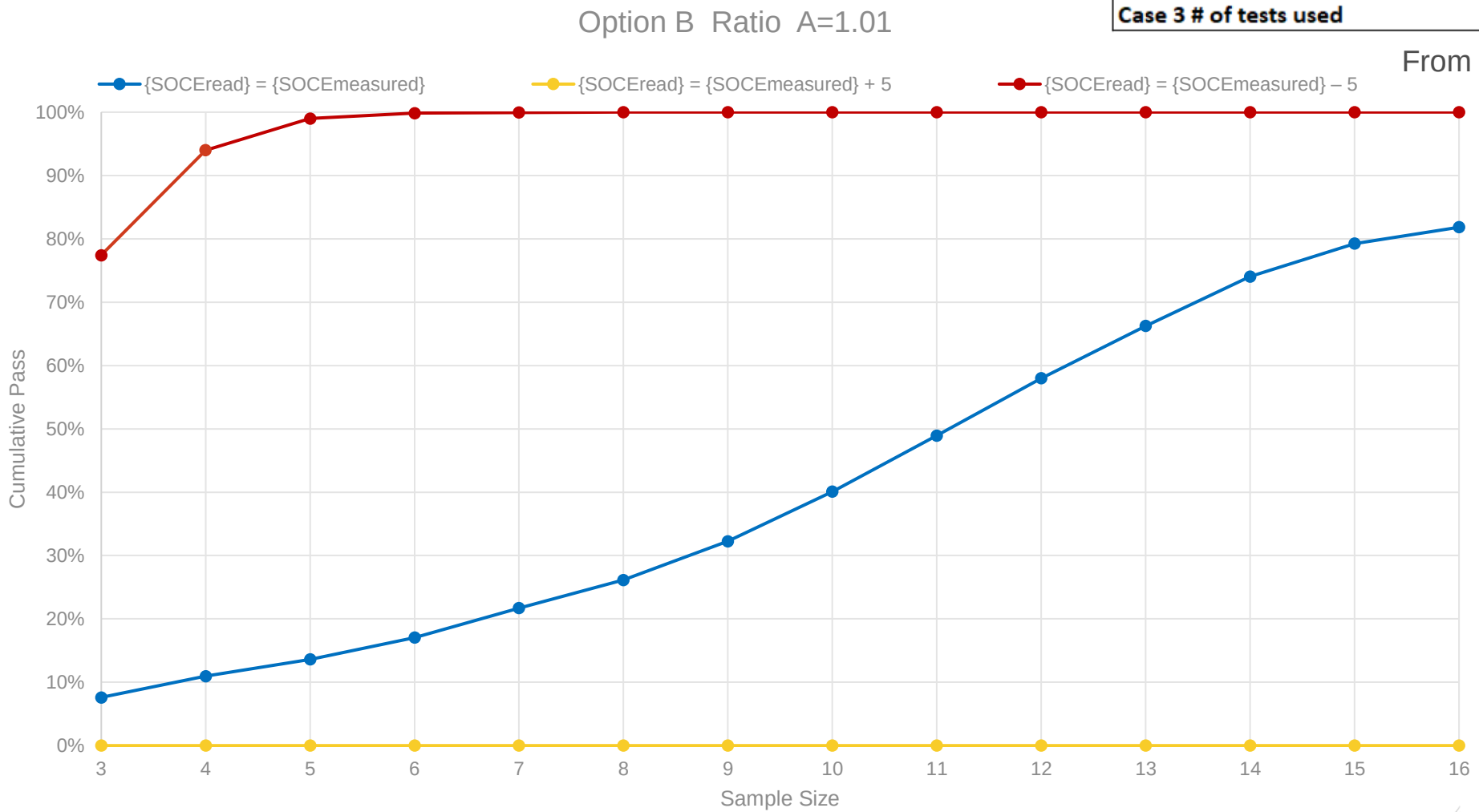
2. Simulating pass/fail statistics with normal distribution

- Assumptions:
  - soc_{read} and $soc_{measured}$ from randomly generated normal distribution
    - soc_{read} shifted above or below the mean value by 5%
    - Varying A value
    - Ratio / Difference method
- Outcomes:
  - Results in line with the presentation from OICA
  - Influence of parameter A on pass/fail decision

soc_{read} shifted above or below the mean value by 5%

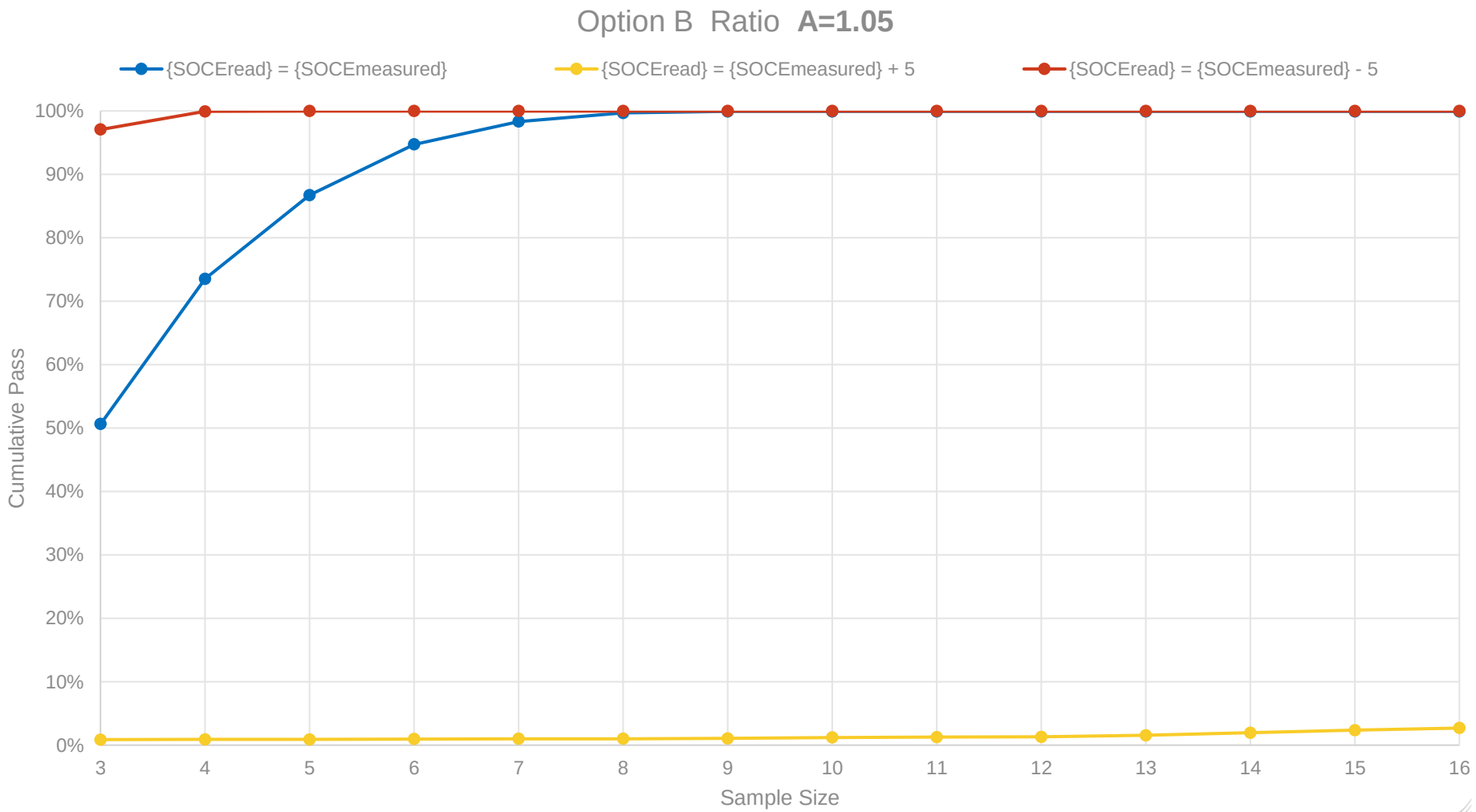
	Opt B
Case 1 ({SOCEread} = {SOCEmeasured})	83%
Case 1 # of tests used	3~16
Case 2 ({SOCEread} = {SOCEmeasured}+5)	0%
Case 2 # of tests used	3~10
Case 3 ({SOCEread} = {SOCEmeasured}-5)	100%
Case 3 # of tests used	3~7

From EVE-46-09e.pdf



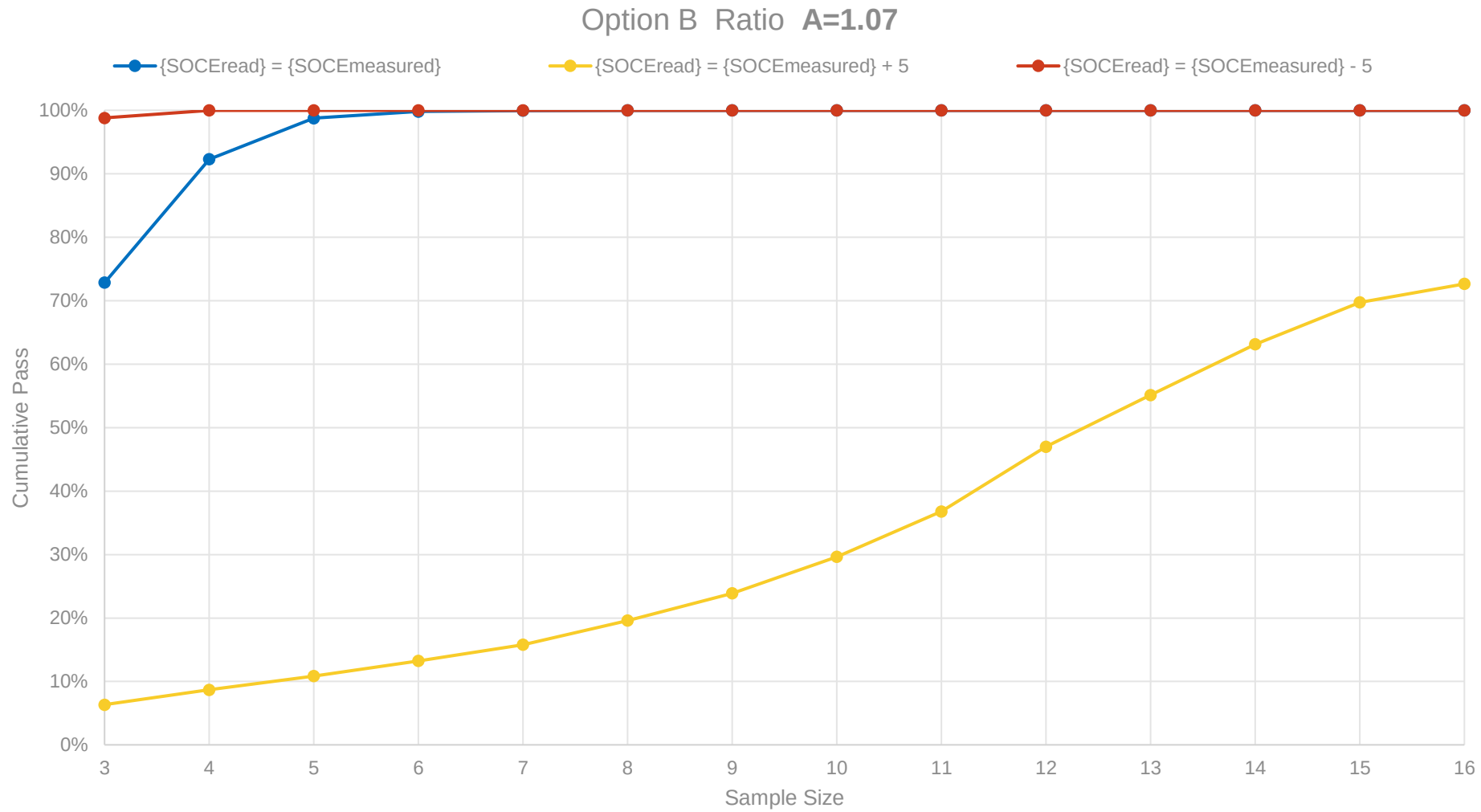
European Commission

soc_{read} shifted above or below the mean value by 5%



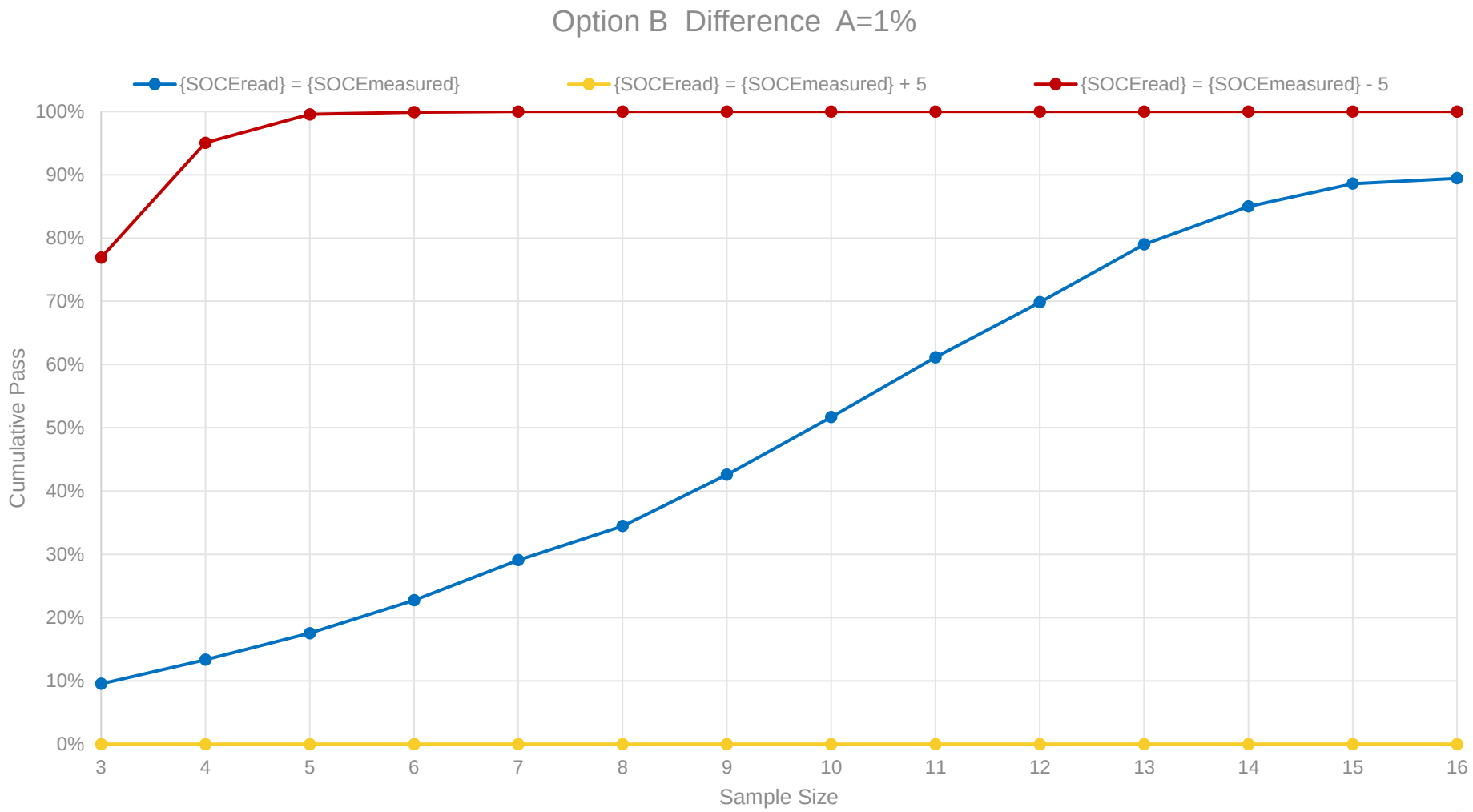
European Commission

soc_{read} shifted above or below the mean value by 5%



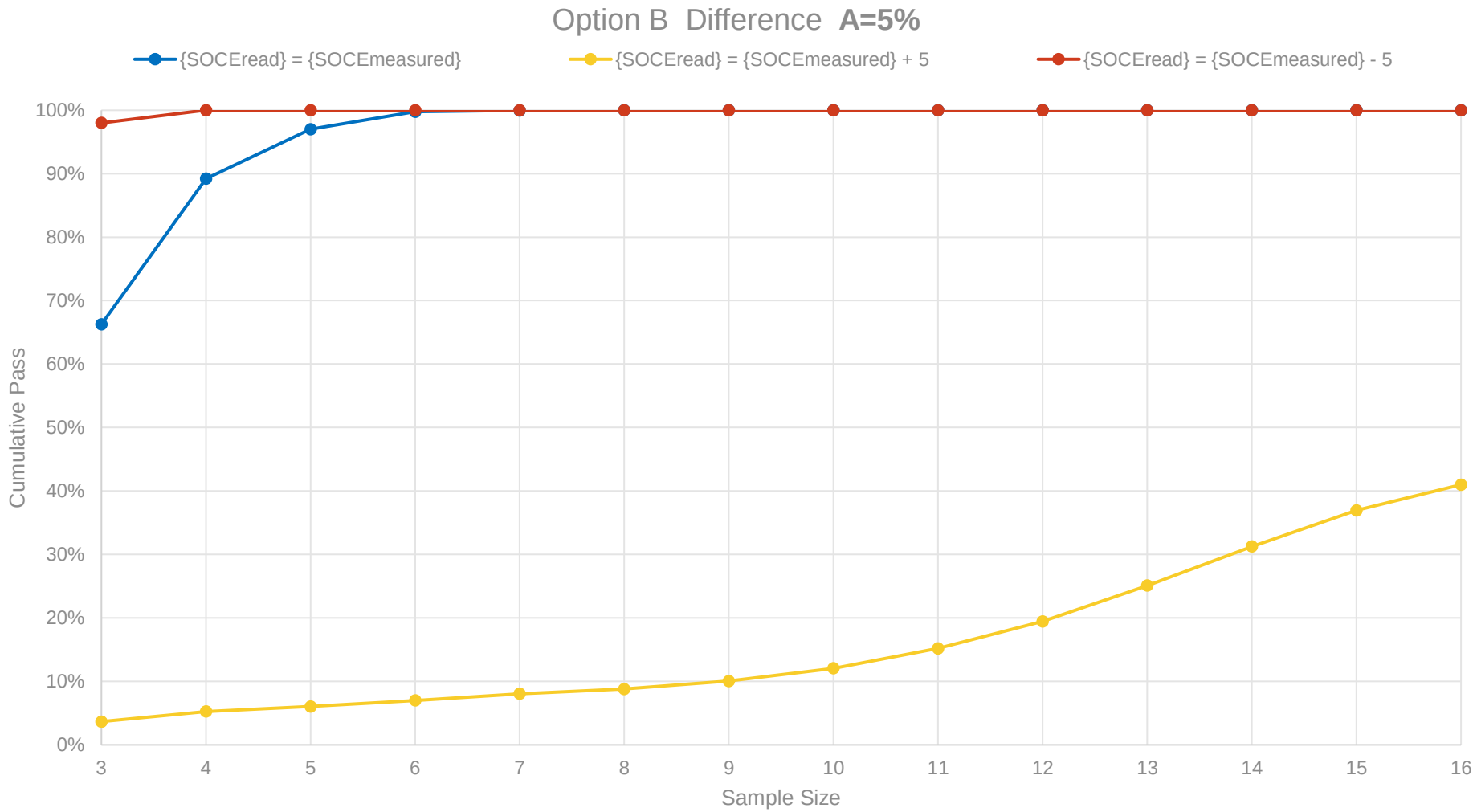
European Commission

soc_{read} shifted above or below the mean value by 5%



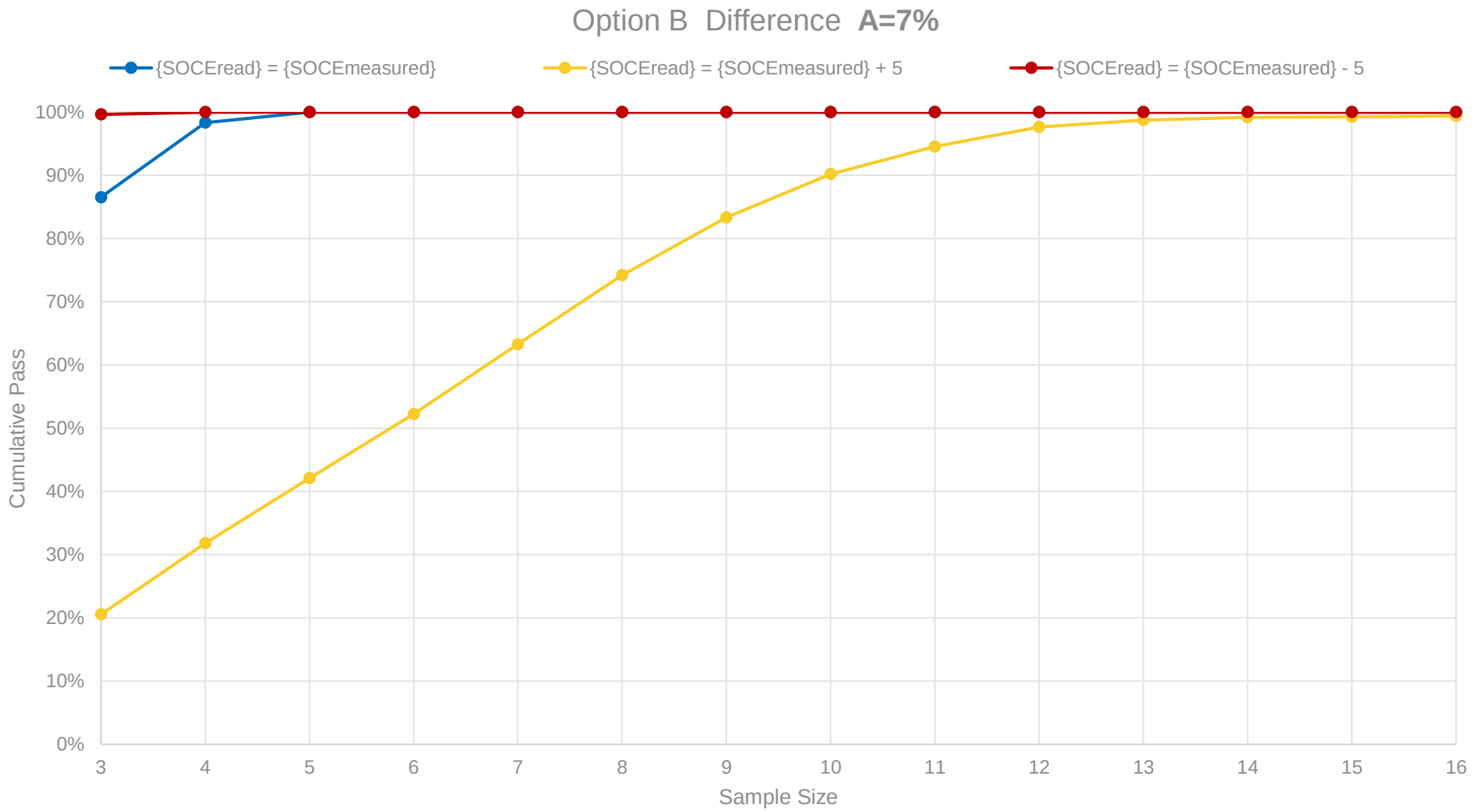
European Commission

soc_{read} shifted above or below the mean value by 5%



European Commission

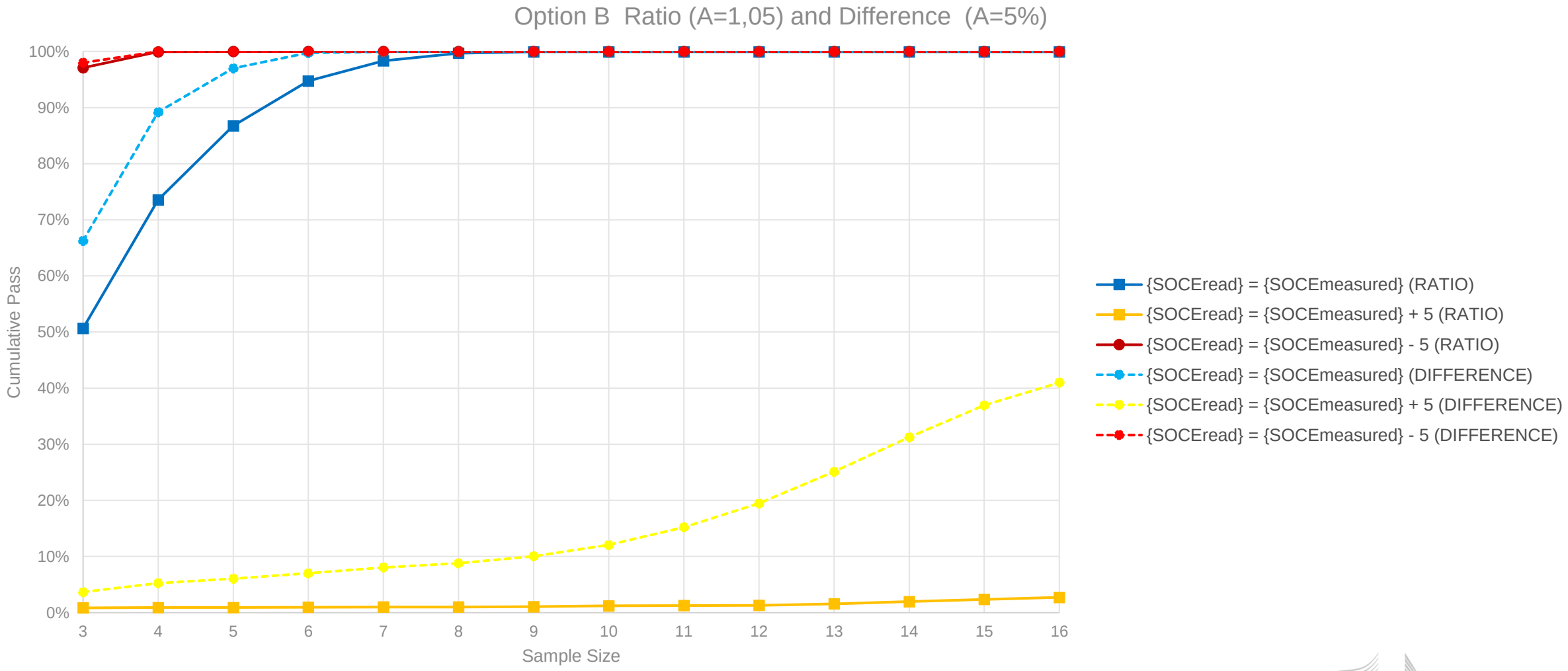
soc_{read} shifted above or below the mean value by 5%



European Commission

soc_{read} shifted above or below the mean value by 5% (Ratio and Difference)

- Ratio method more stringent for same A value



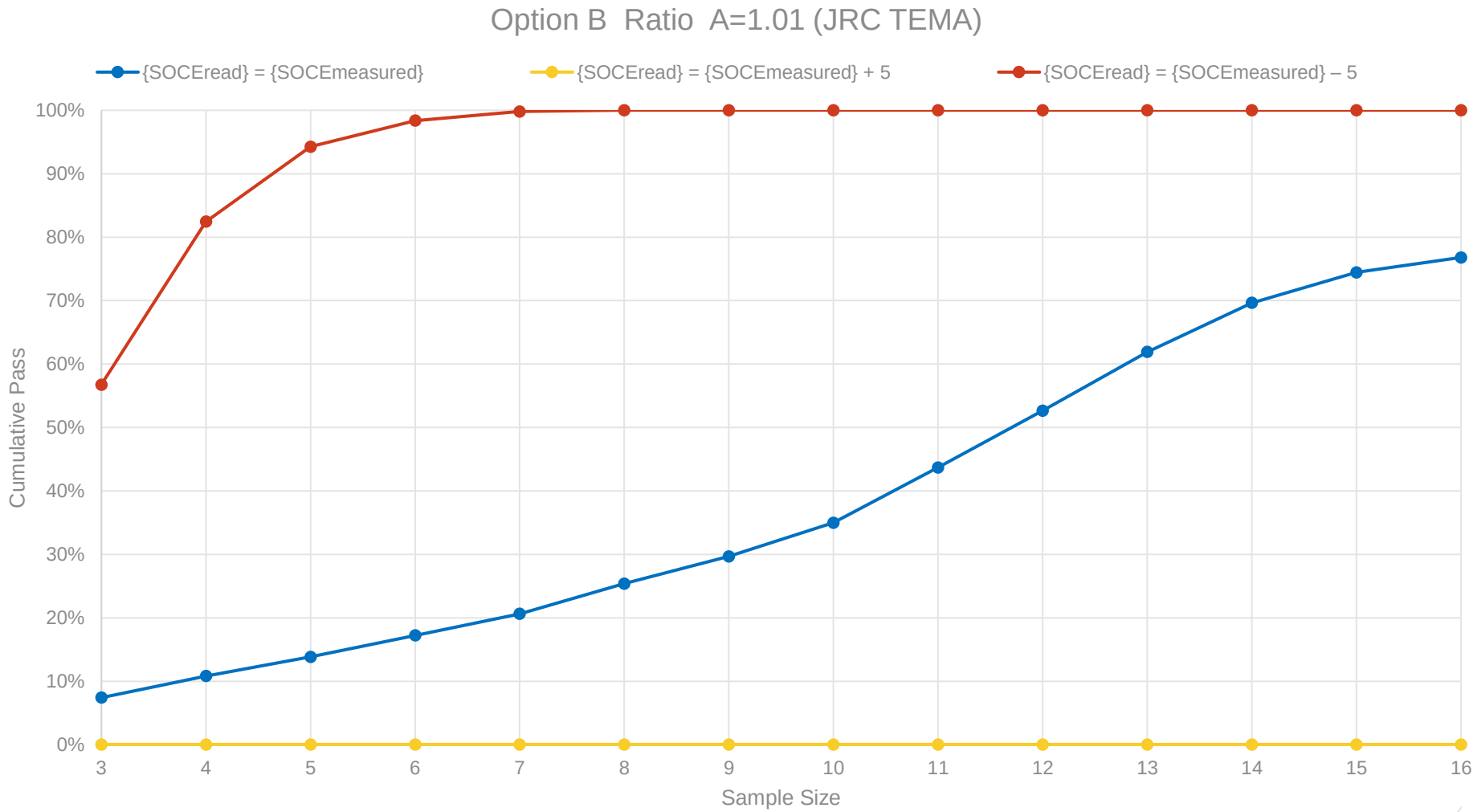
European Commission

3. Simulating pass/fail statistics with JRC TEMA data

- Assumptions:
  - soc_{read} and $soc_{measured}$ from JRC TEMA simulated data distributions (ref. EVE-41-03e)
    - soc_{read} shifted above or below the mean value by 5%
    - Varying A value
    - Ratio / Difference method

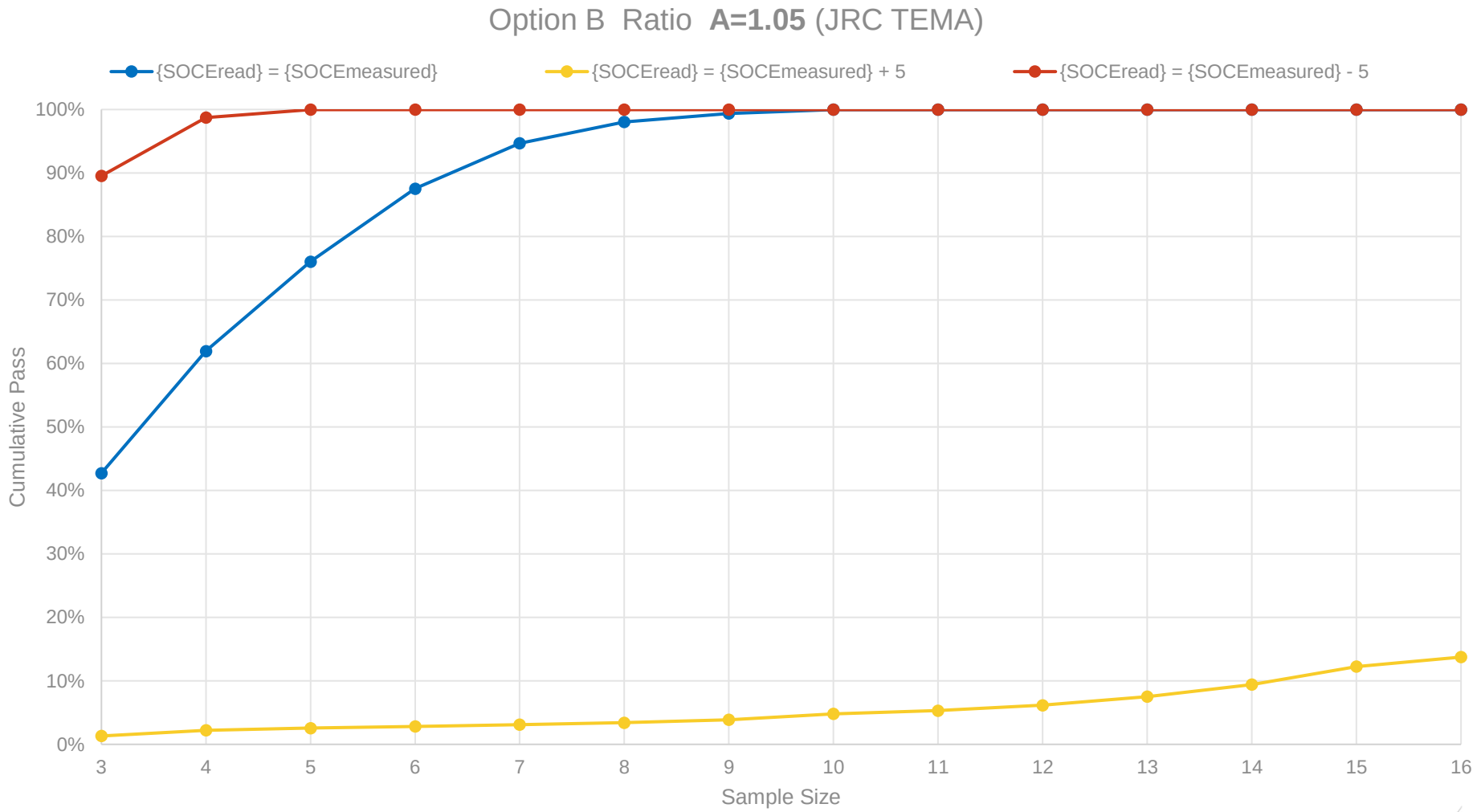
- Outcomes:
  - Influence of parameter A on pass/fail decision
  - Difference method more stringent for same A value

soc_{read} shifted above or below the mean value by 5% (JRC TEMA)



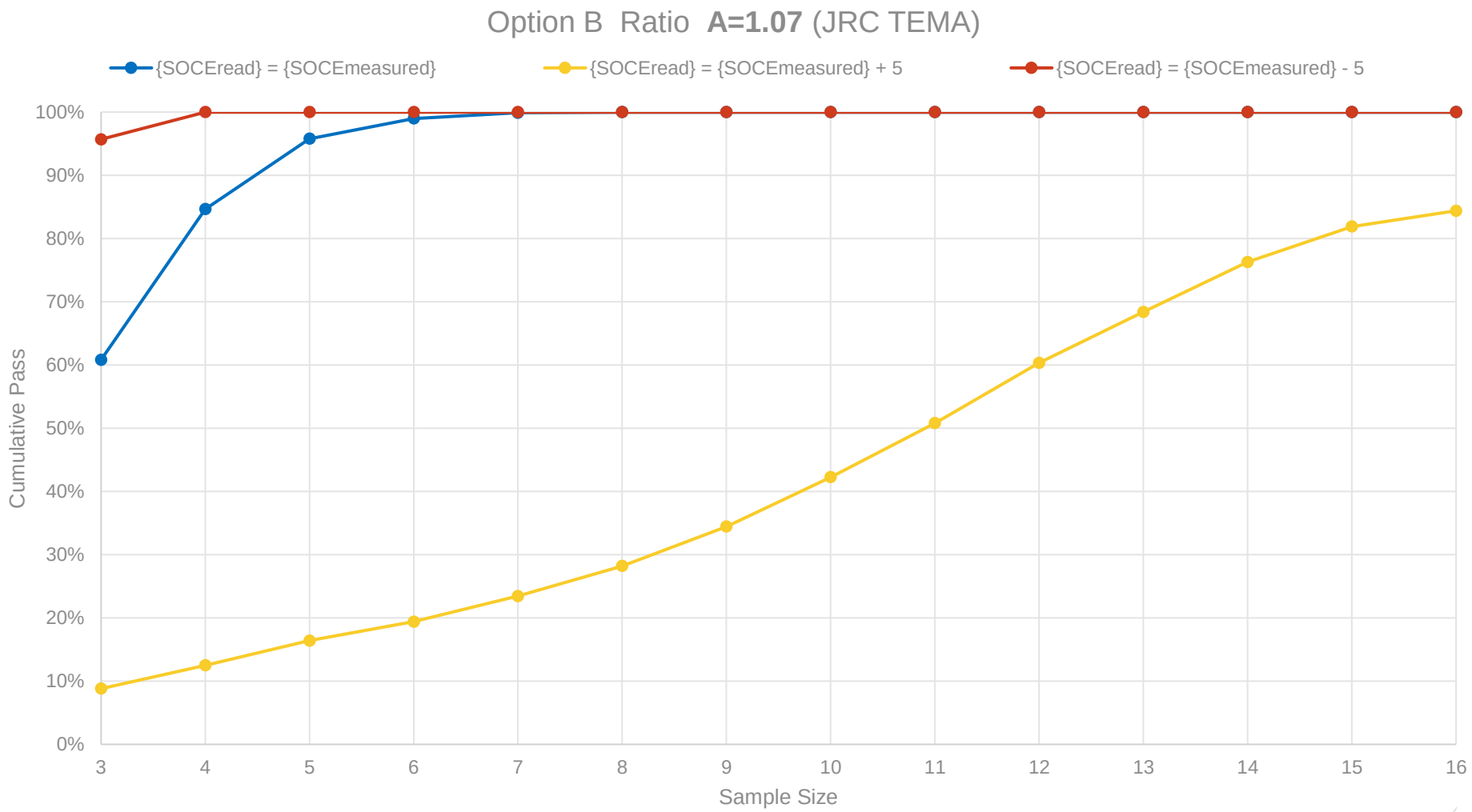
European Commission

soc_{read} shifted above or below the mean value by 5% (JRC TEMA)



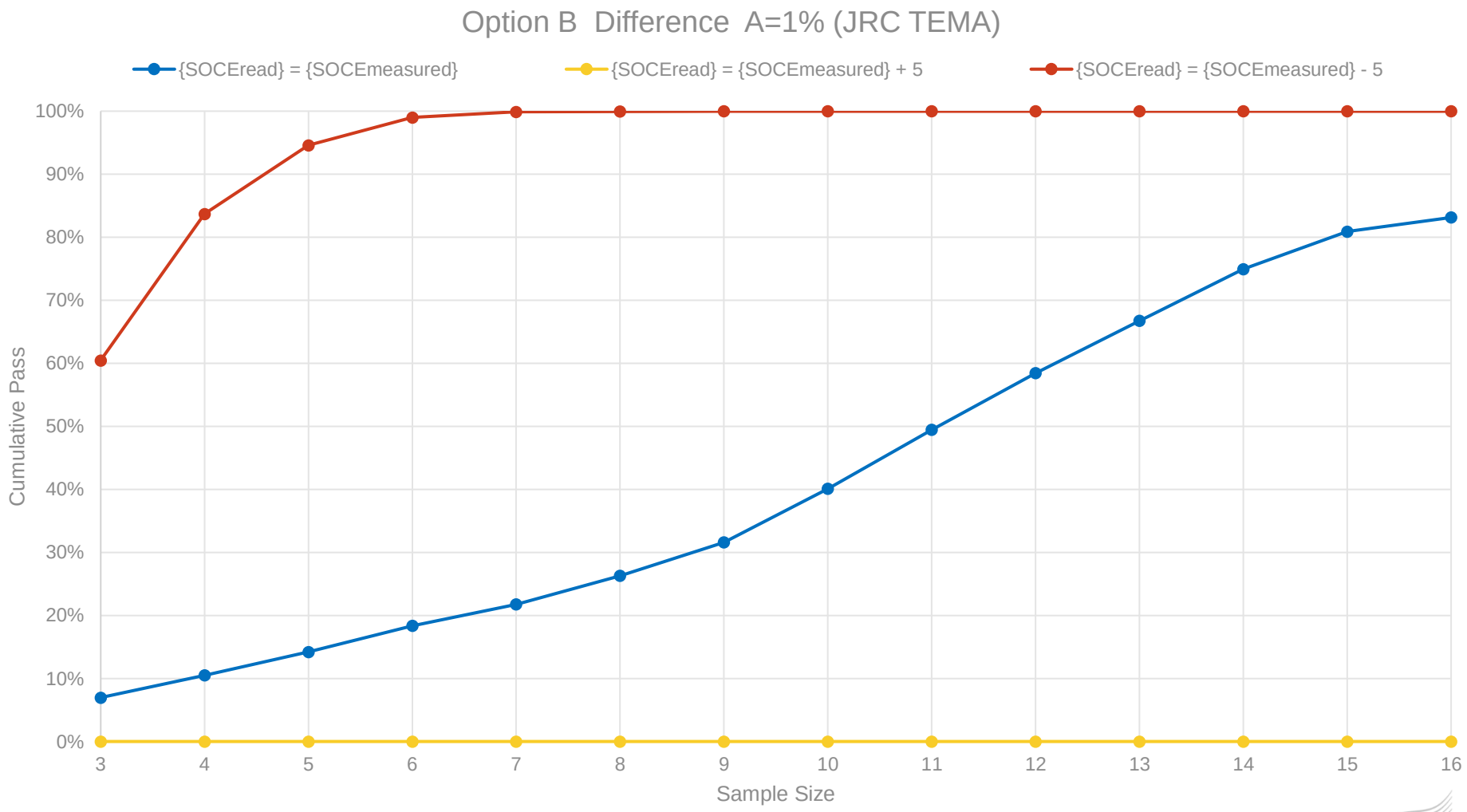
European Commission

soc_{read} shifted above or below the mean value by 5% (JRC TEMA)



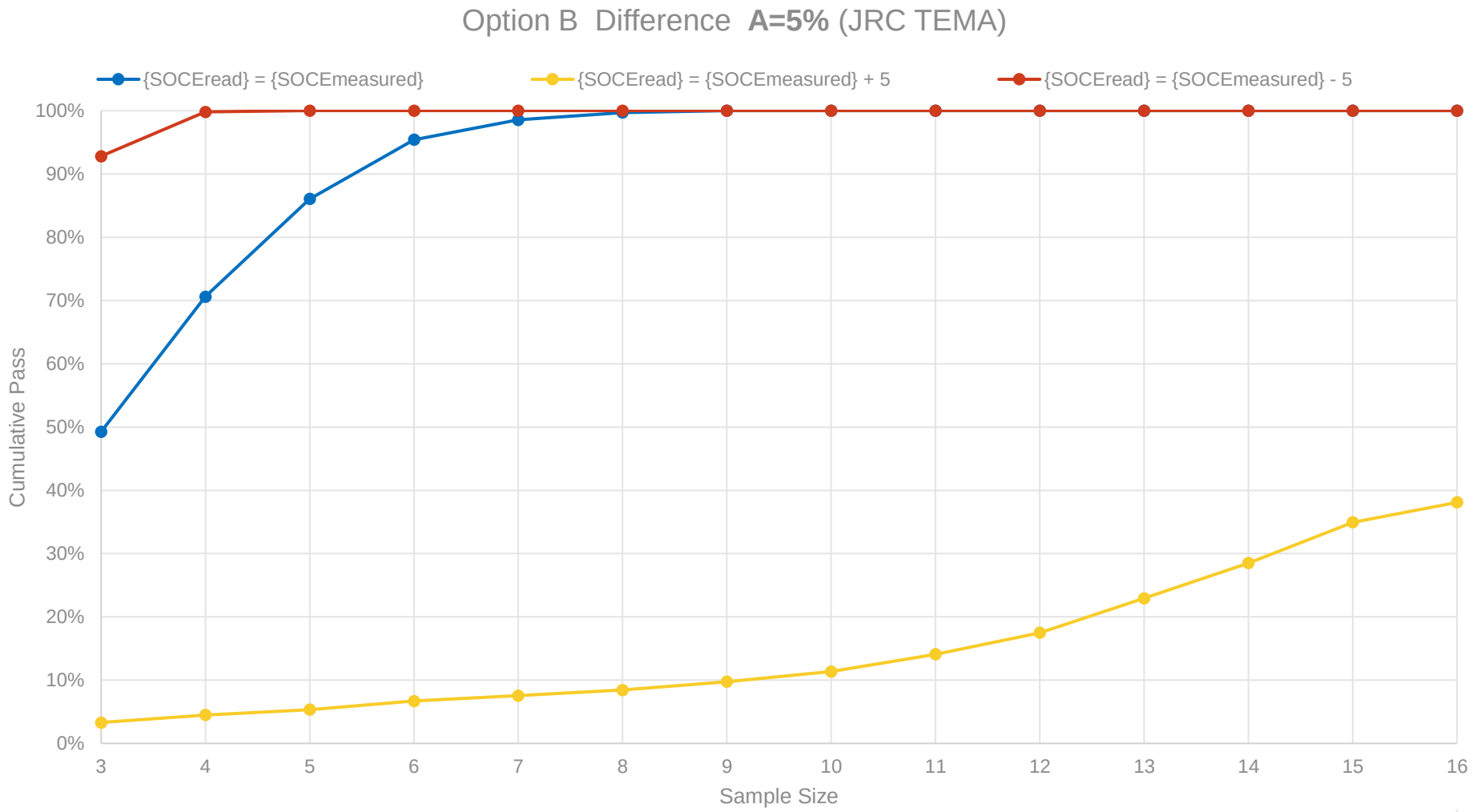
European Commission

soc_{read} shifted above or below the mean value by 5% (JRC TEMA)



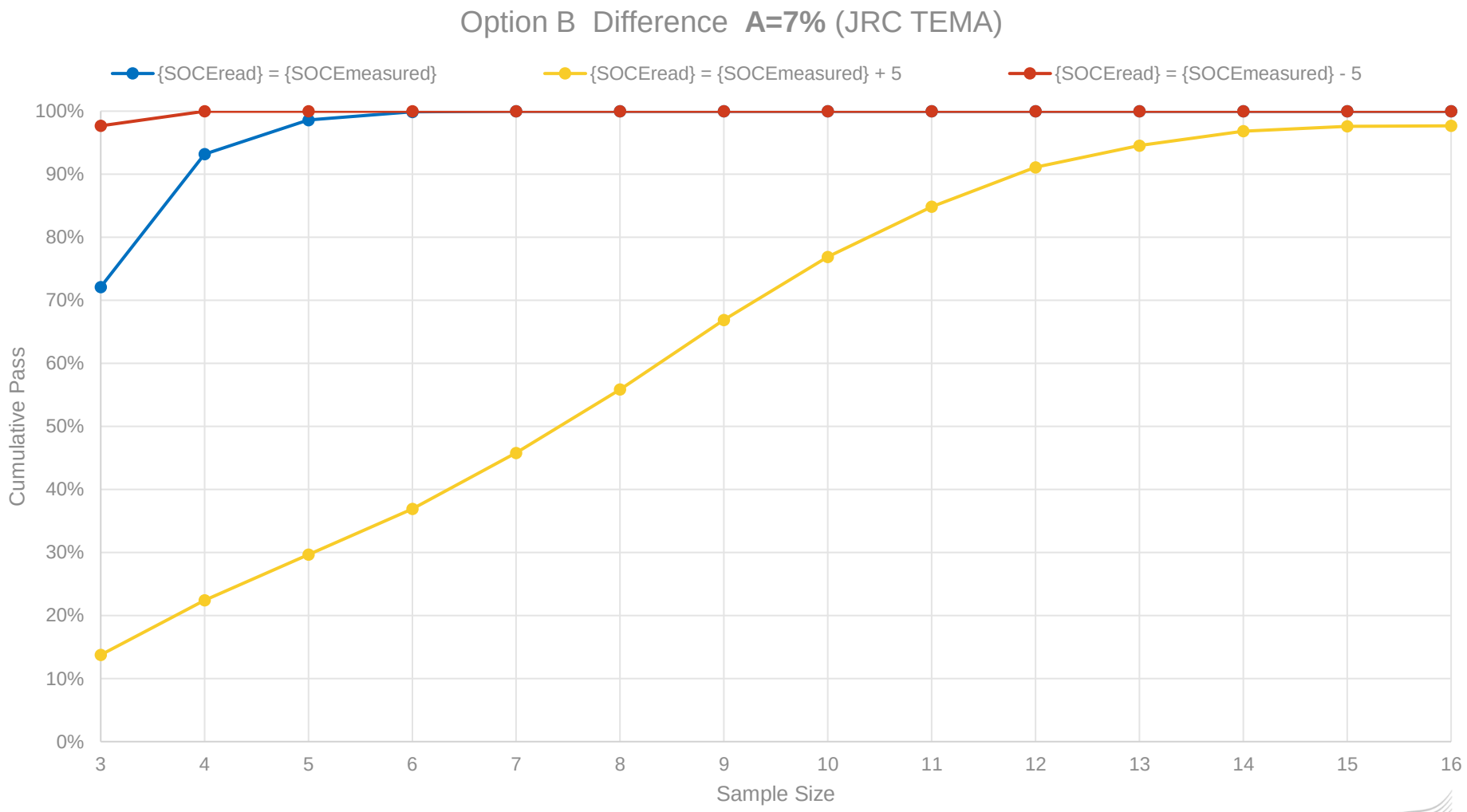
European Commission

soc_{read} shifted above or below the mean value by 5% (JRC TEMA)



European Commission

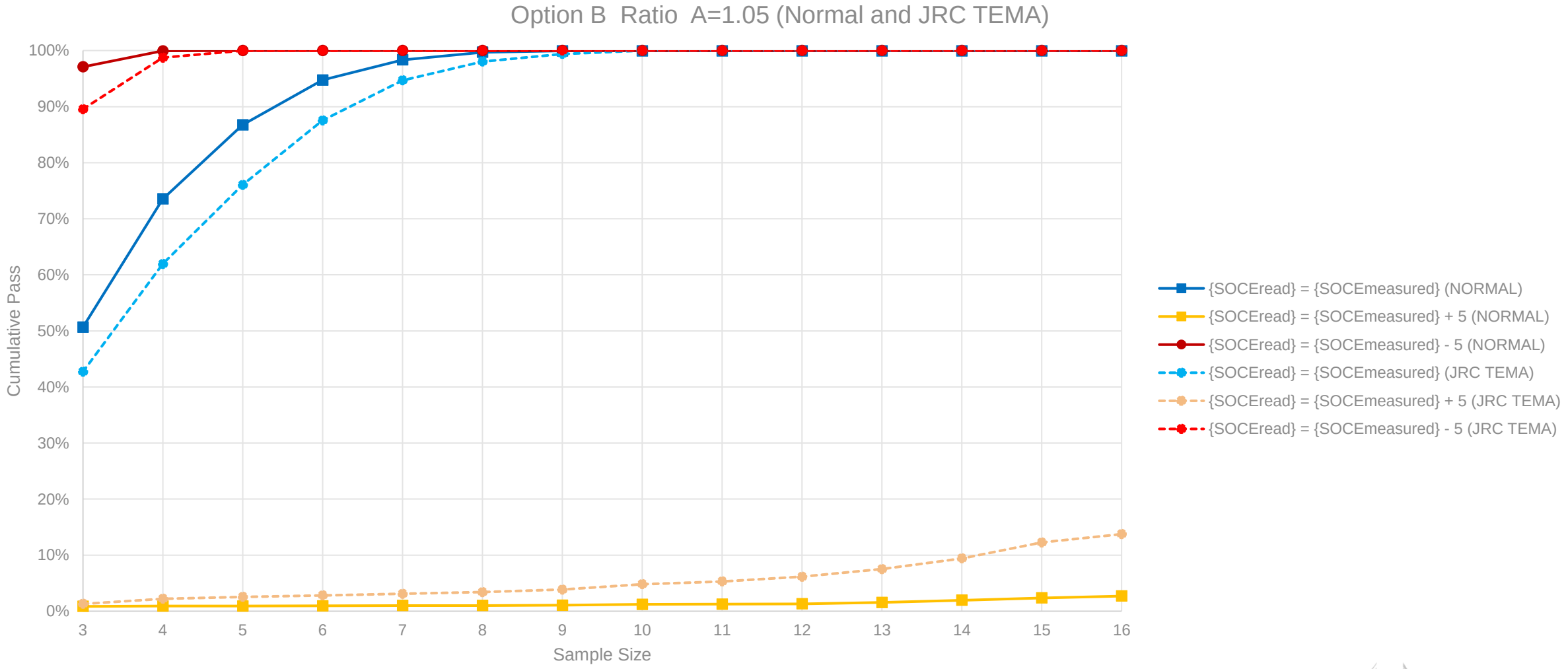
soc_{read} shifted above or below the mean value by 5% (JRC TEMA)



European Commission

soc_{read} shifted above or below the mean value by 5% (Normal and JRC TEMA)

- Statistics from JRC TEMA more affected by higher area of the tails

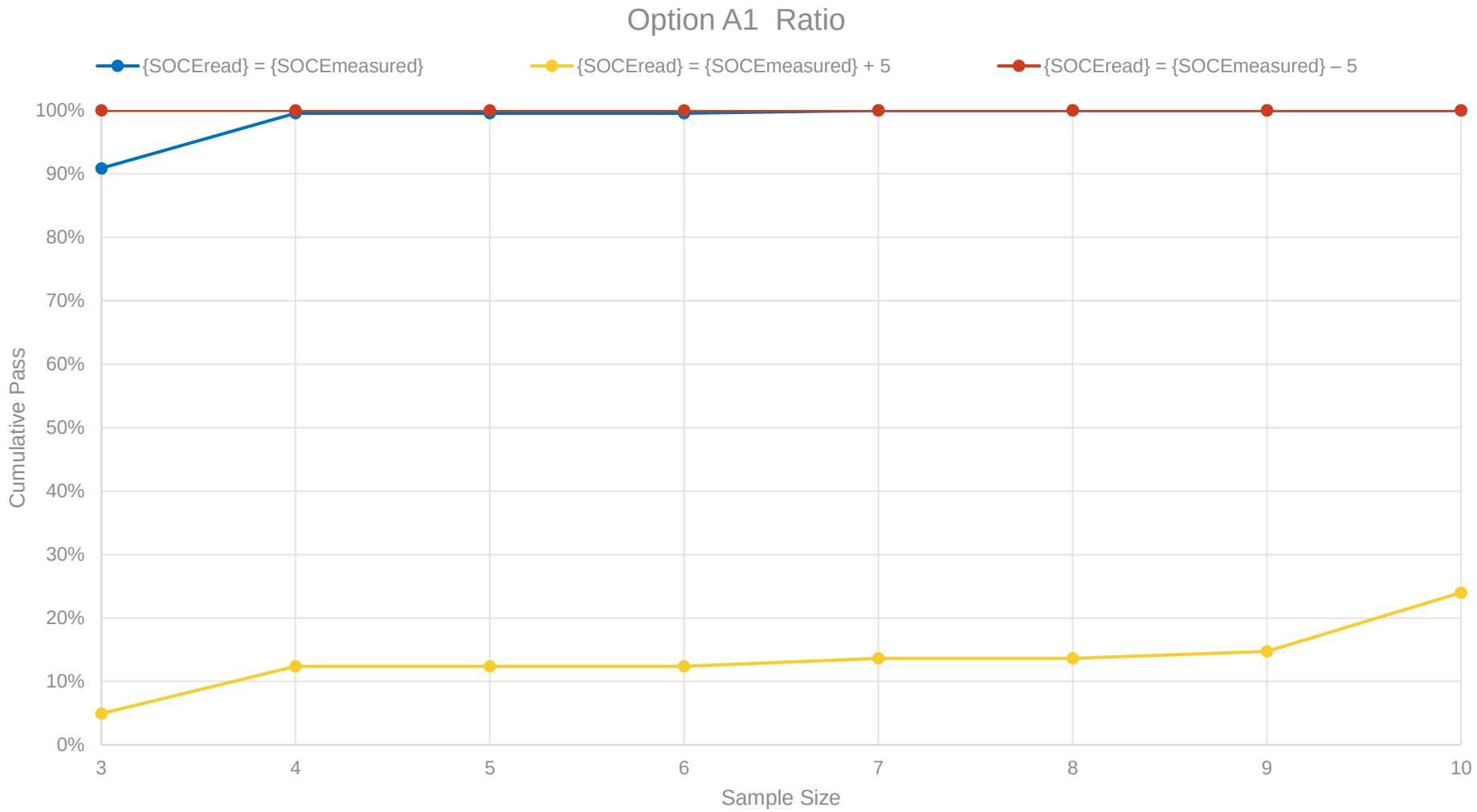


European Commission

4. Comparing with Options A1, A2

- Assumptions:
  - soc_{read} and $soc_{measured}$ from randomly generated normal distribution
    - soc_{read} shifted above or below the mean value by 5%
- Outcomes:
  - Options A1 and A2 high pass rates for samples taken from population above mean value

Comparing with Options A1, A2

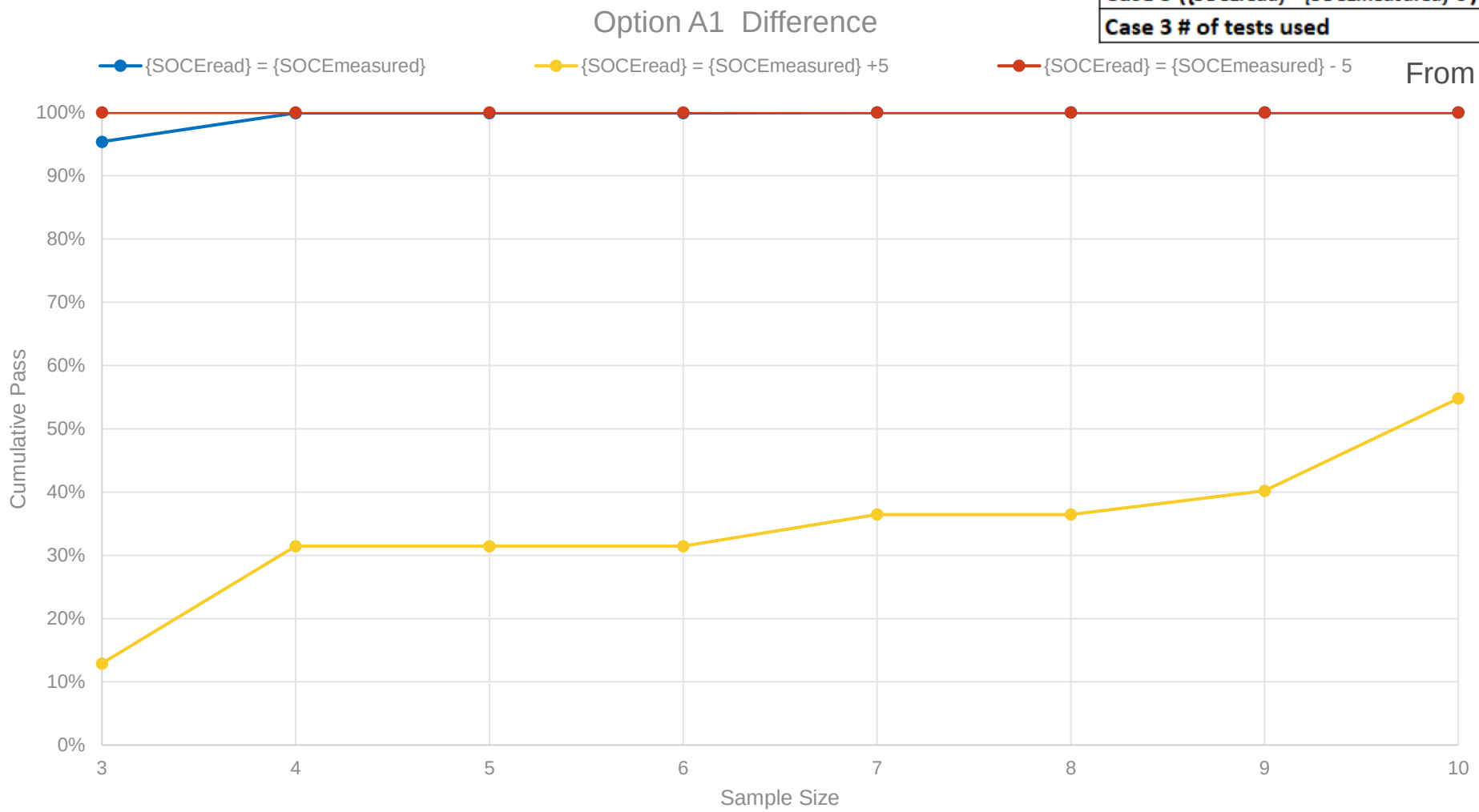


European Commission

Comparing with Options A1, A2

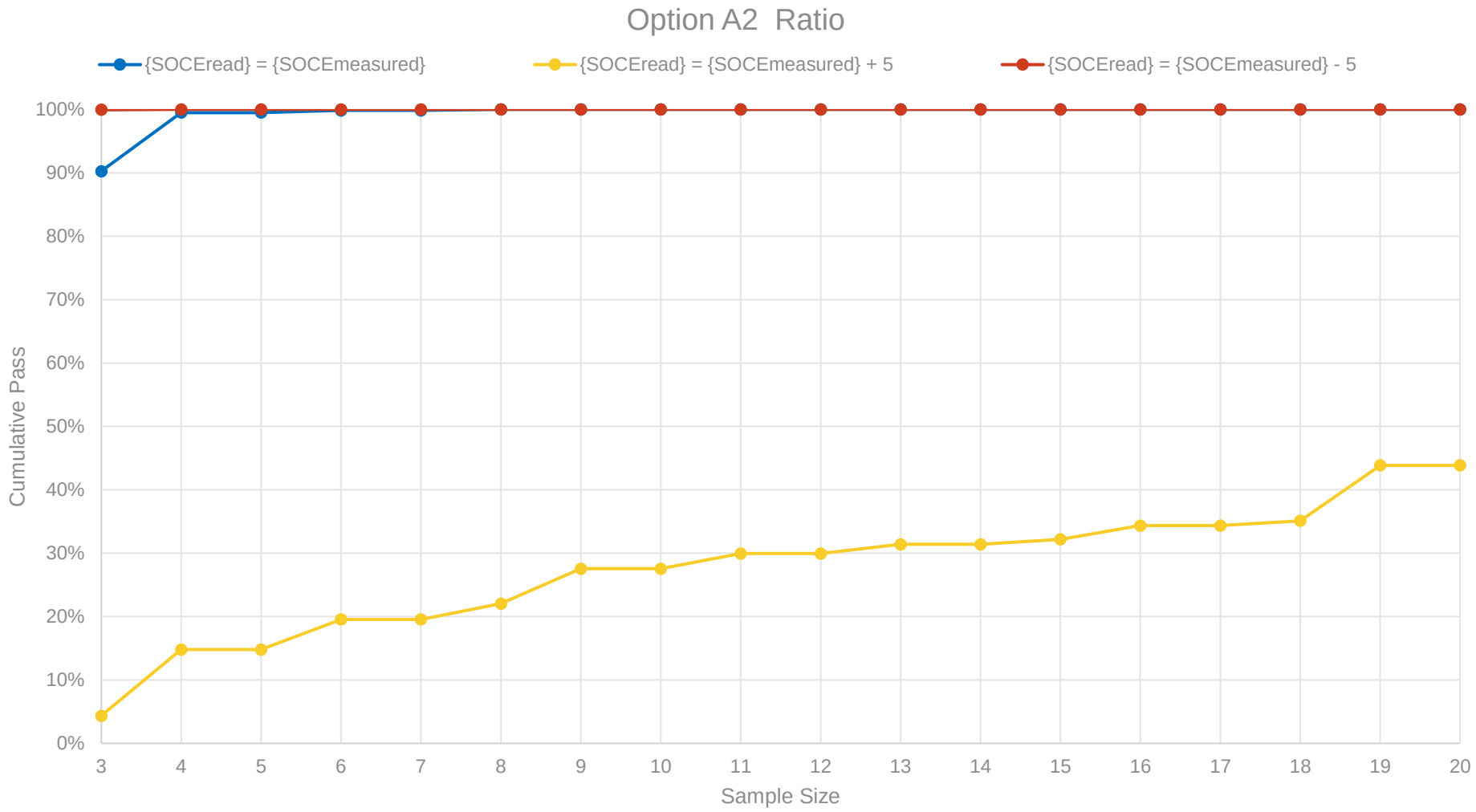
	Opt A1
Case 1 ({SOCEread} = {SOCEmeasured})	100%
Case 1 # of tests used	3~7
Case 2 ({SOCEread} = {SOCEmeasured}+5)	55%
Case 2 # of tests used	3~10
Case 3 ({SOCEread} = {SOCEmeasured}-5)	100%
Case 3 # of tests used	3

From EVE-46-09e.pdf



European Commission

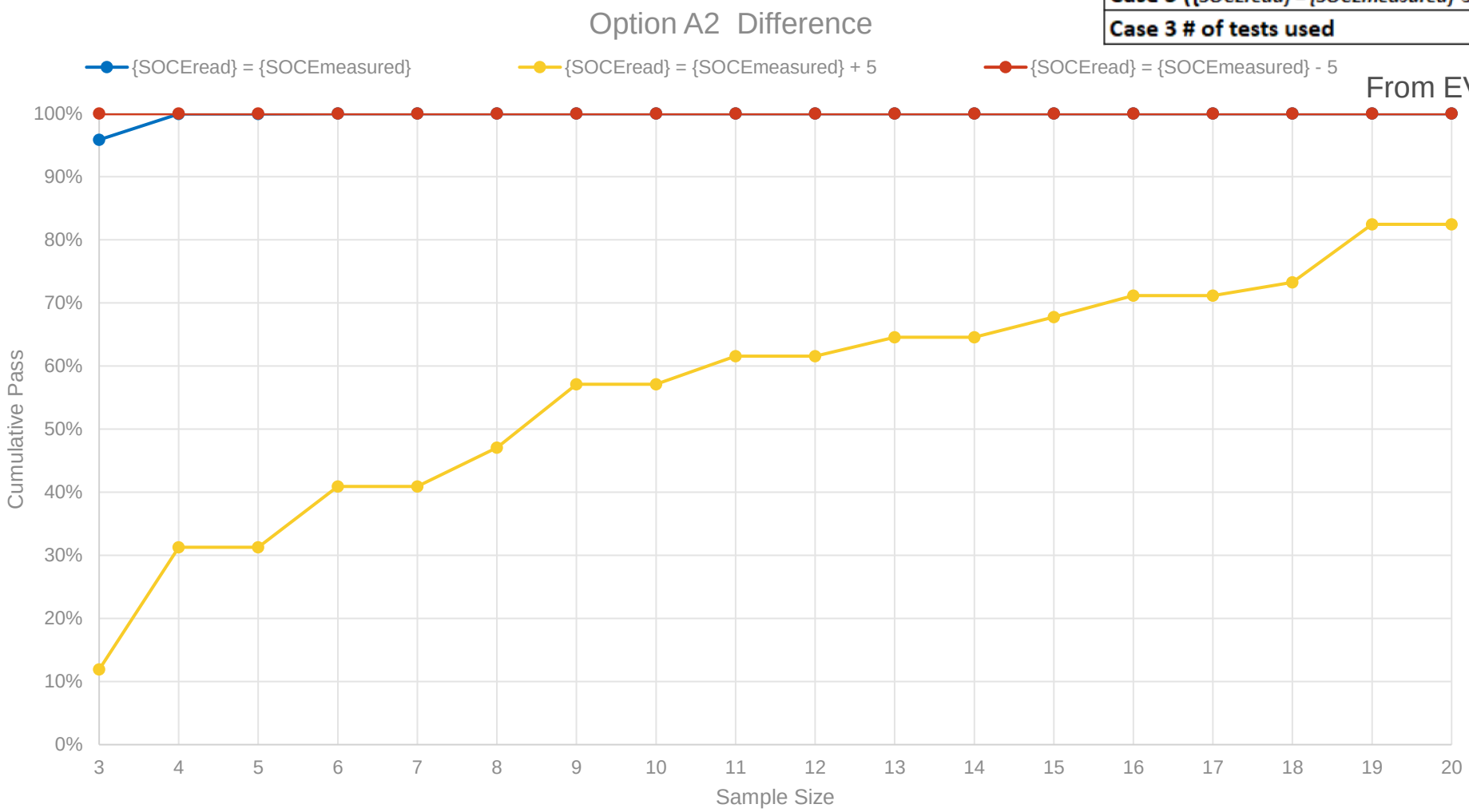
Comparing with Options A1, A2



European Commission

Comparing with Options A1, A2

	Opt A2
Case 1 ({SOCEread} = {SOCEmeasured})	100%
Case 1 # of tests used	3~7
Case 2 ({SOCEread} = {SOCEmeasured}+5)	80%
Case 2 # of tests used	3~20
Case 3 ({SOCEread} = {SOCEmeasured}-5)	100%
Case 3 # of tests used	3



From EVE-46-09e.pdf

5. Changing Confidence Level

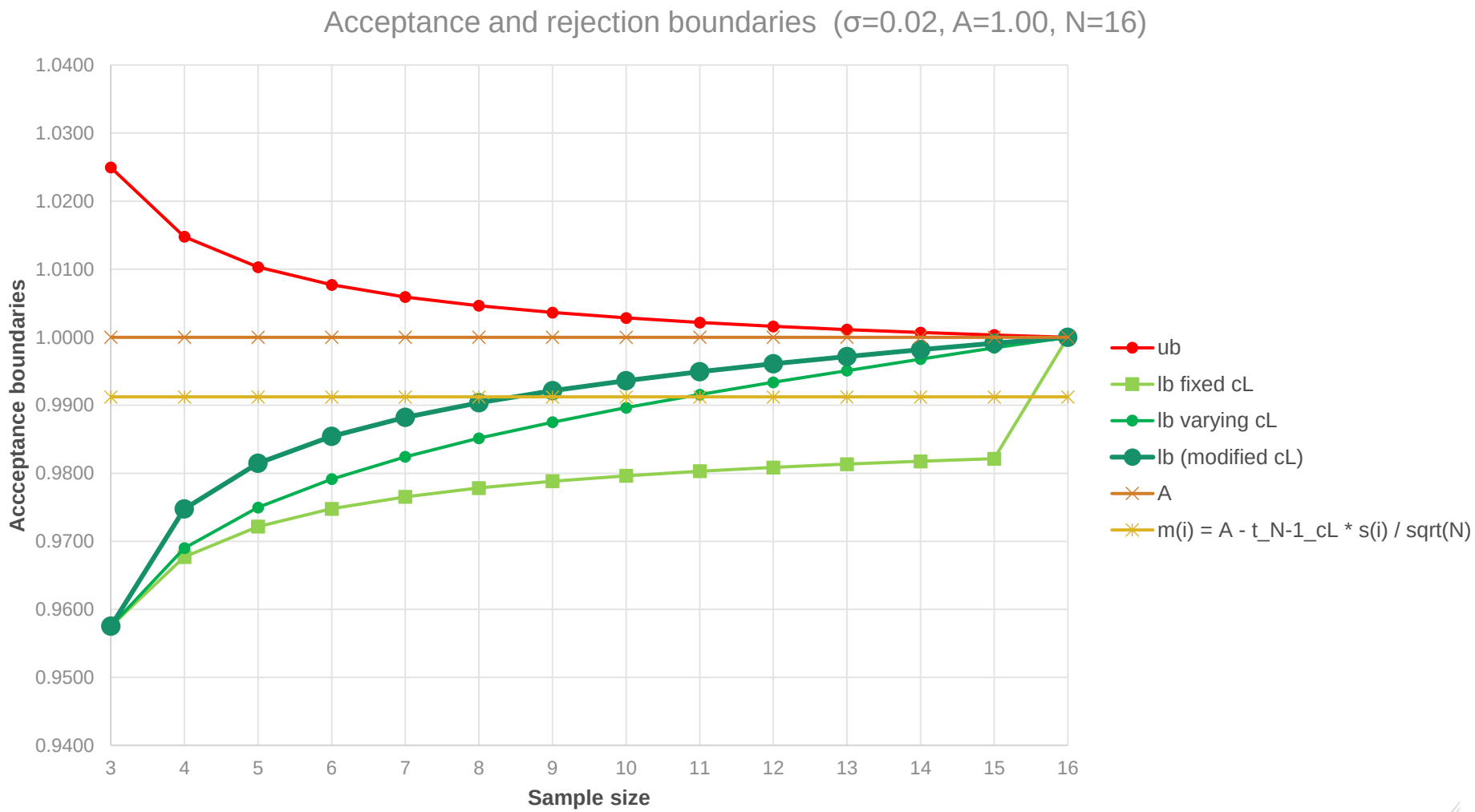
- Assumptions:
  - soc_{read} and $soc_{measured}$ from randomly generated normal distribution
    - soc_{read} shifted above or below the mean value by 5%
    - Varying A value
    - Ratio / Difference method
  - **Confidence Level decreases constant with sample size**

~~`cL_lo = [0.95 0.945 0.935 0.92 0.9  0.875 0.845 0.81 0.77 0.725 0.675 0.62 0.56 0.5];`~~ growing difference for bigger sizes

`cL_lo = [0.950 0.915 0.881 0.846 0.812 0.777 0.742 0.708 0.673 0.638 0.604 0.569 0.535 0.500];` constant difference

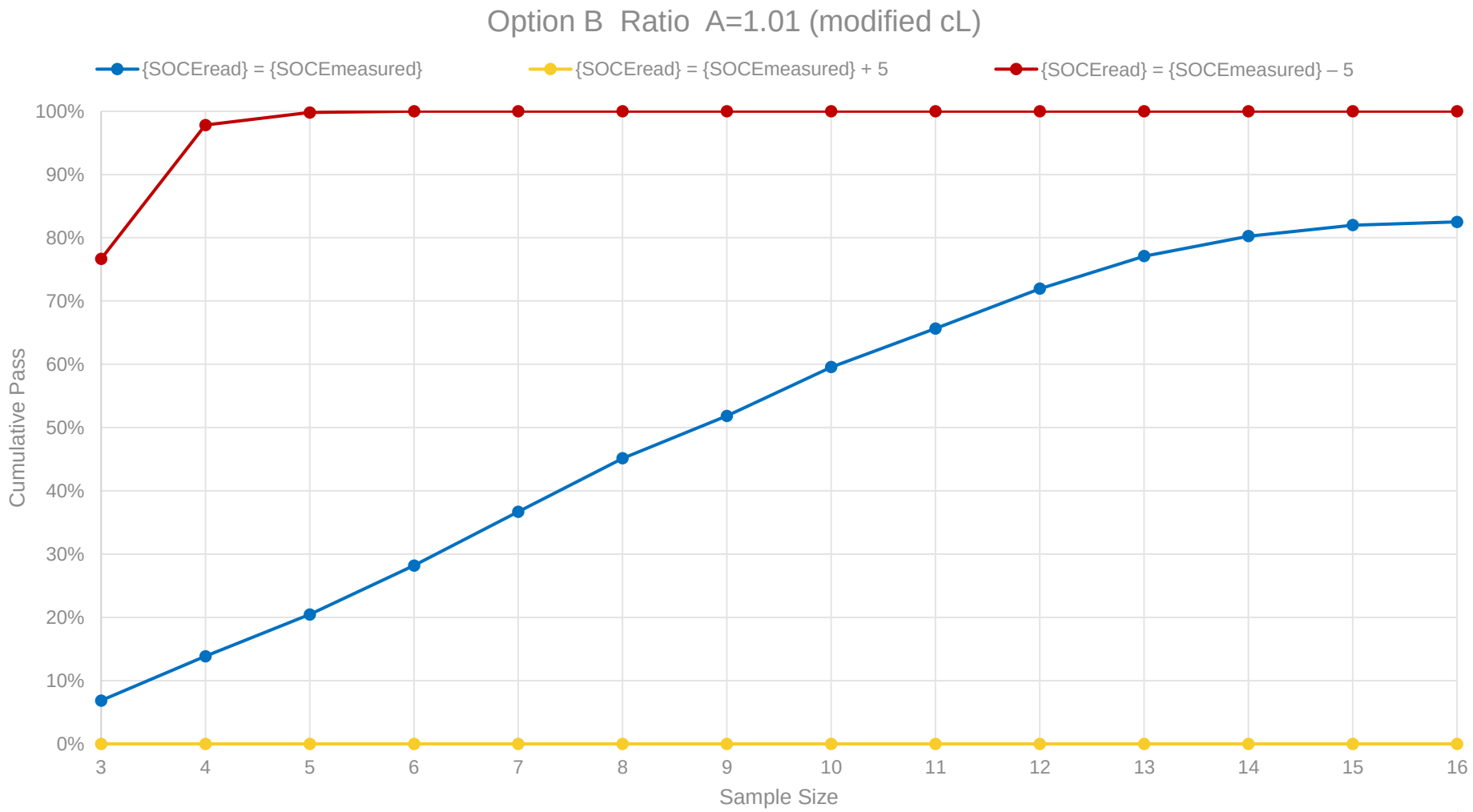
- Outcomes:
  - Influence of parameter A on pass/fail decision
  - Difference method more stringent for same A value
  - A value less influence on Difference method
  - **Higher Pass rates for lower sample sizes with decreased confidence level**

5. Changing Confidence Level



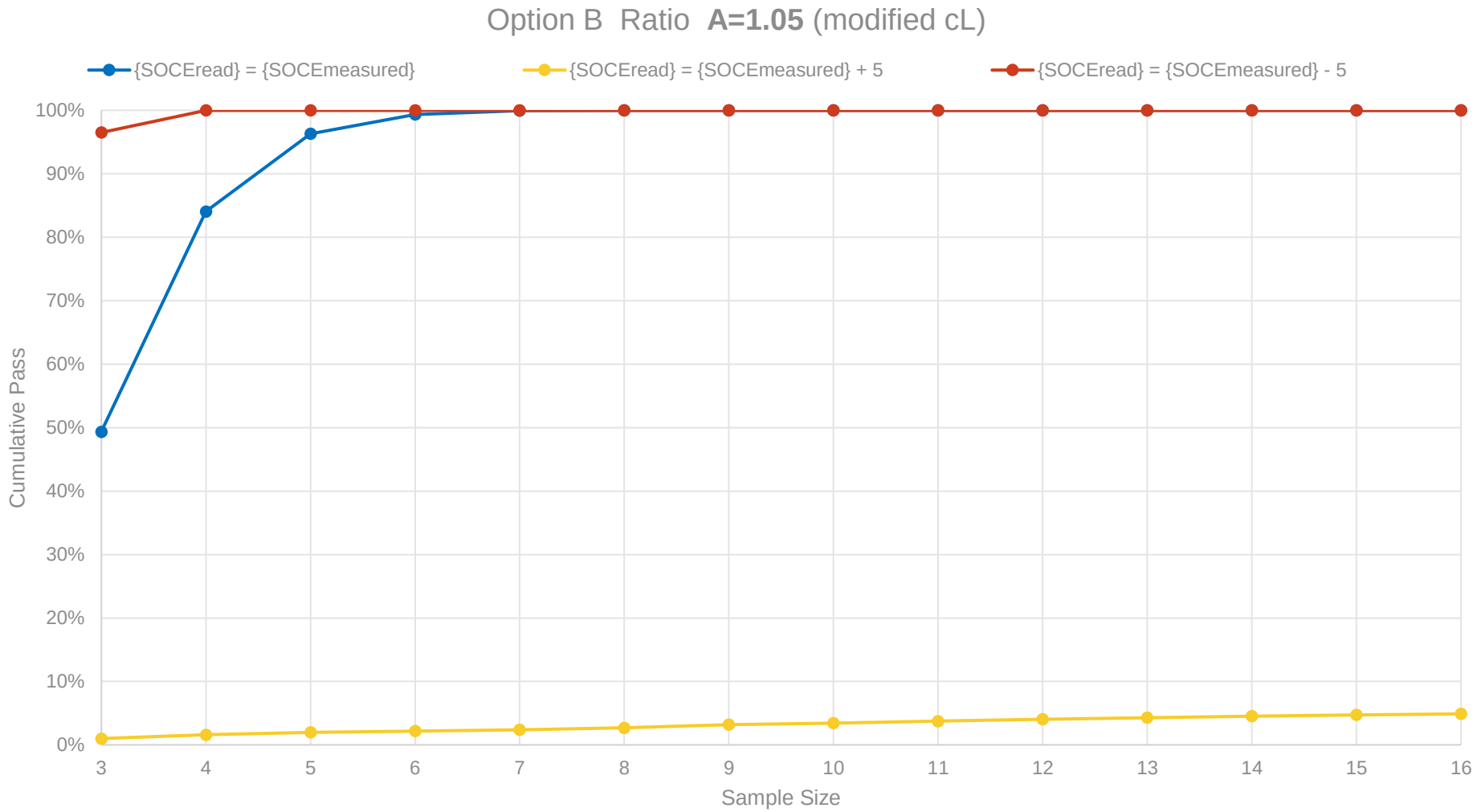
European Commission

soc_{read} shifted above or below the mean value by 5% (modified cL)



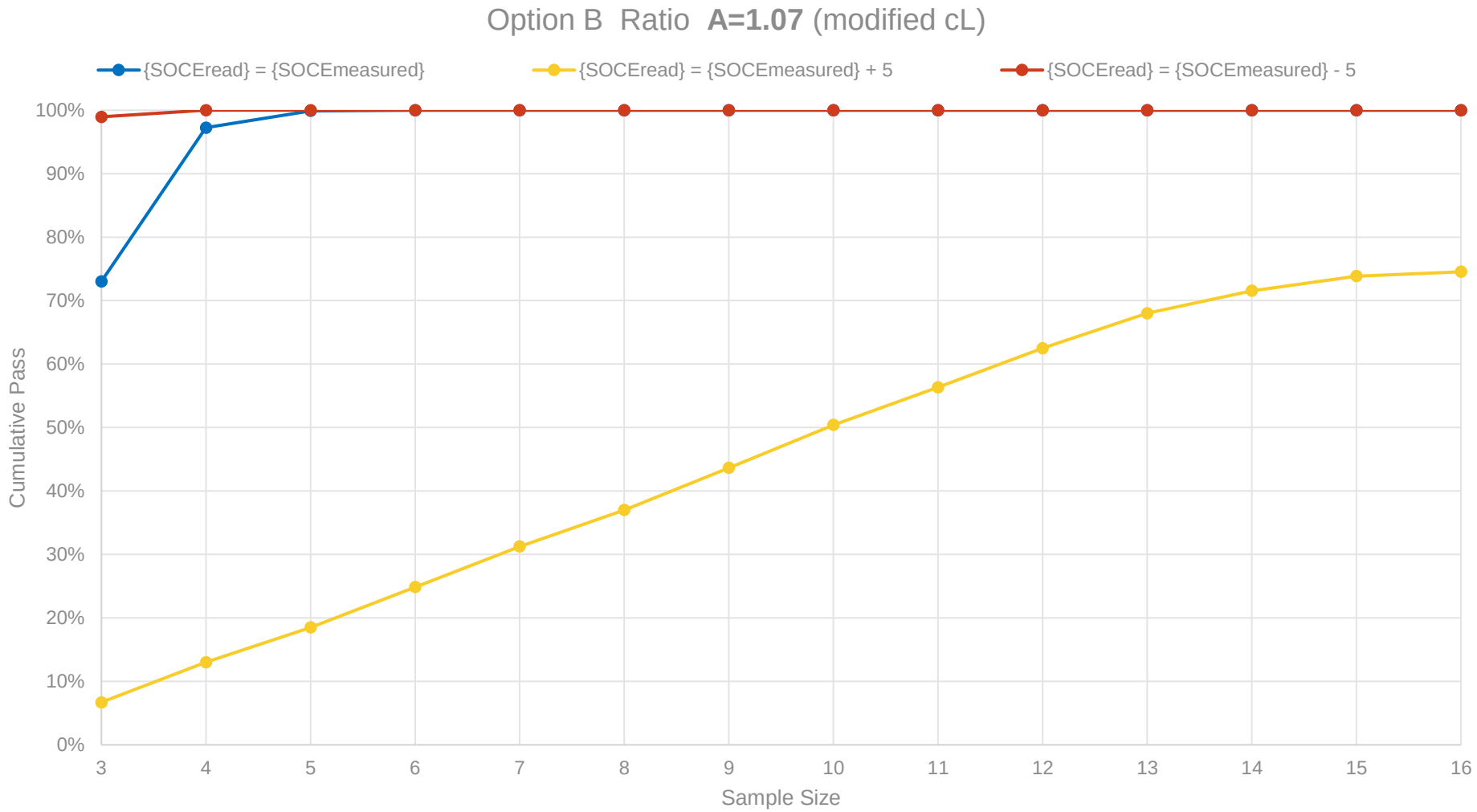
European Commission

soc_{read} shifted above or below the mean value by 5% (modified cL)



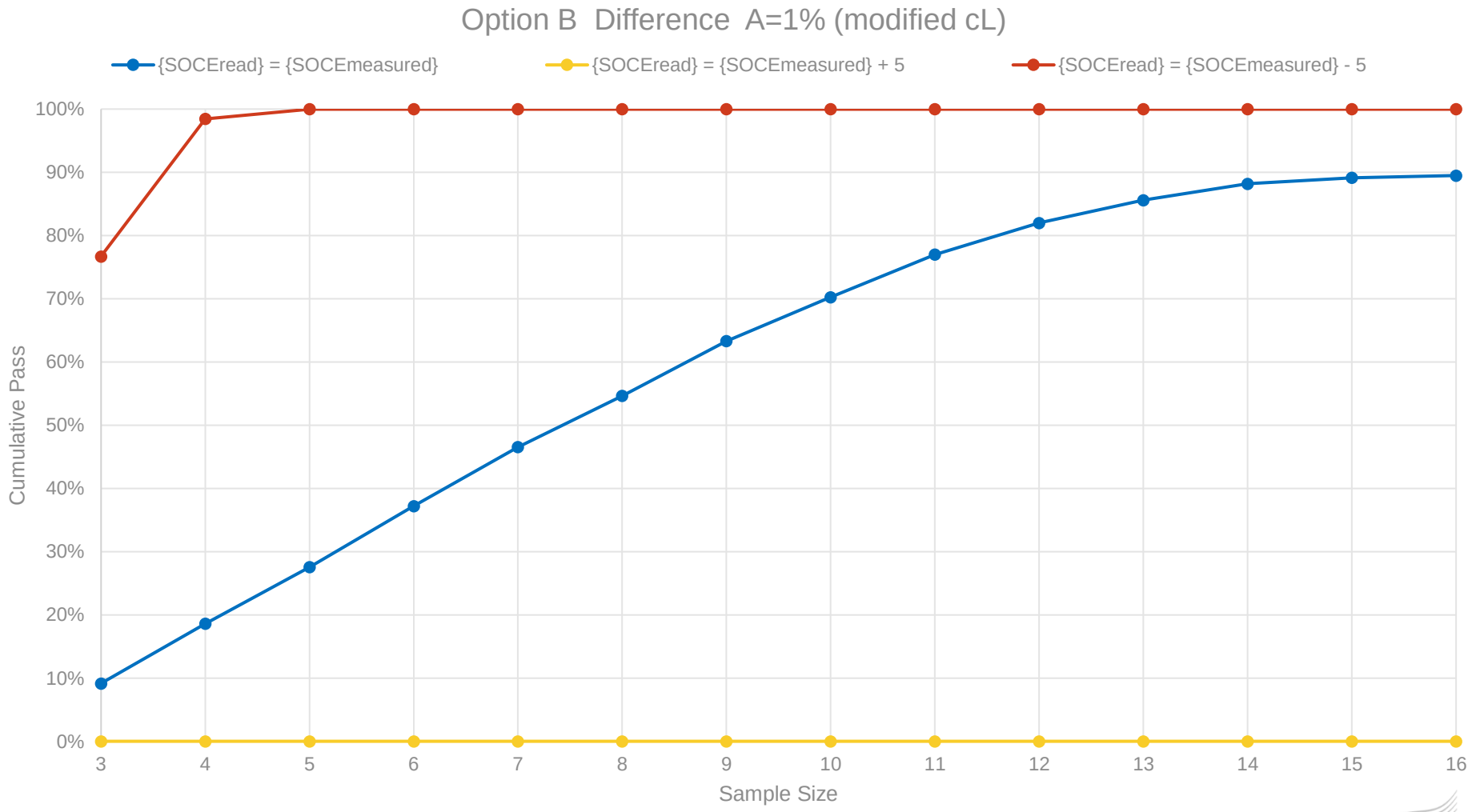
European Commission

soc_{read} shifted above or below the mean value by 5% (modified cL)



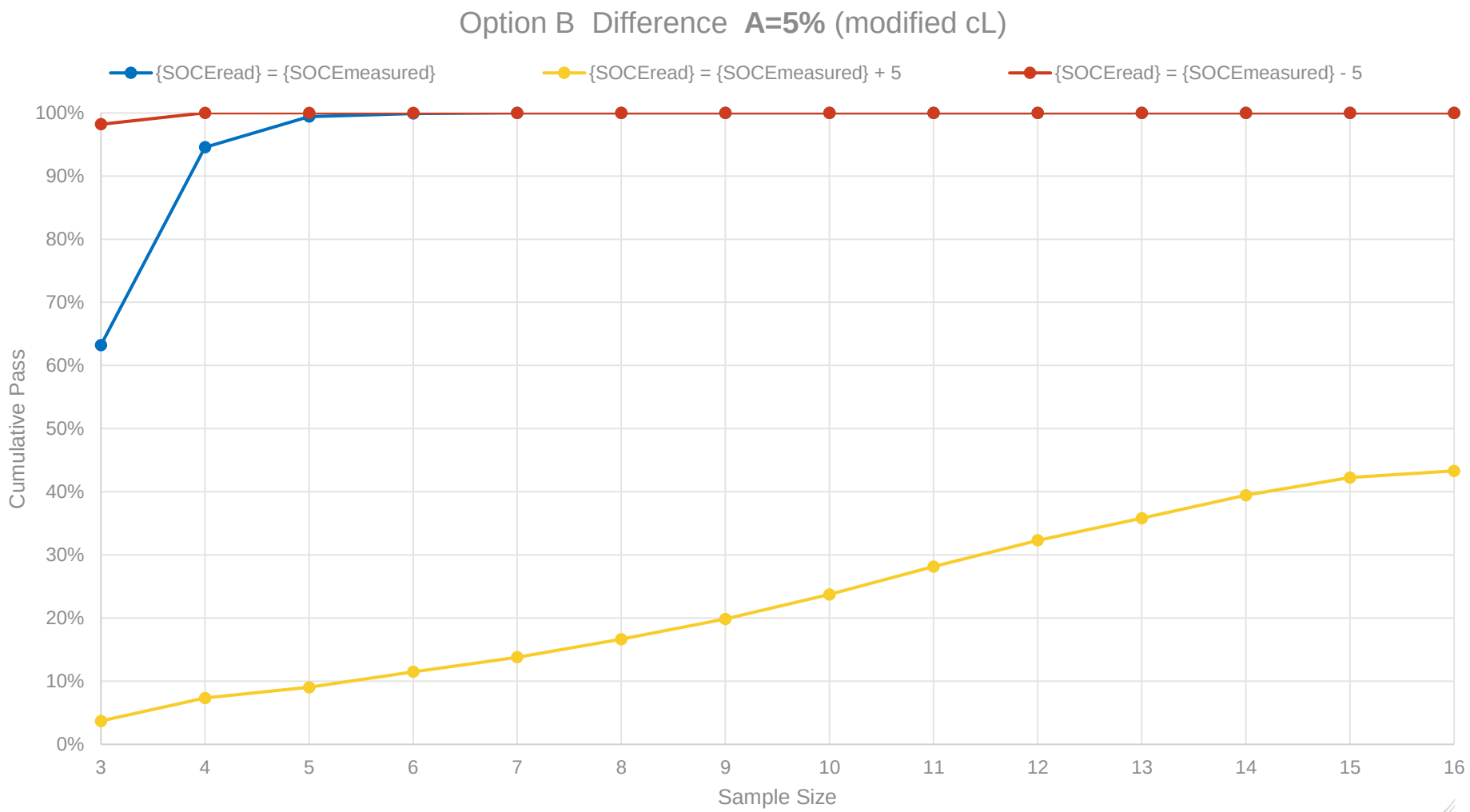
European Commission

soc_{read} shifted above or below the mean value by 5% (modified cL)



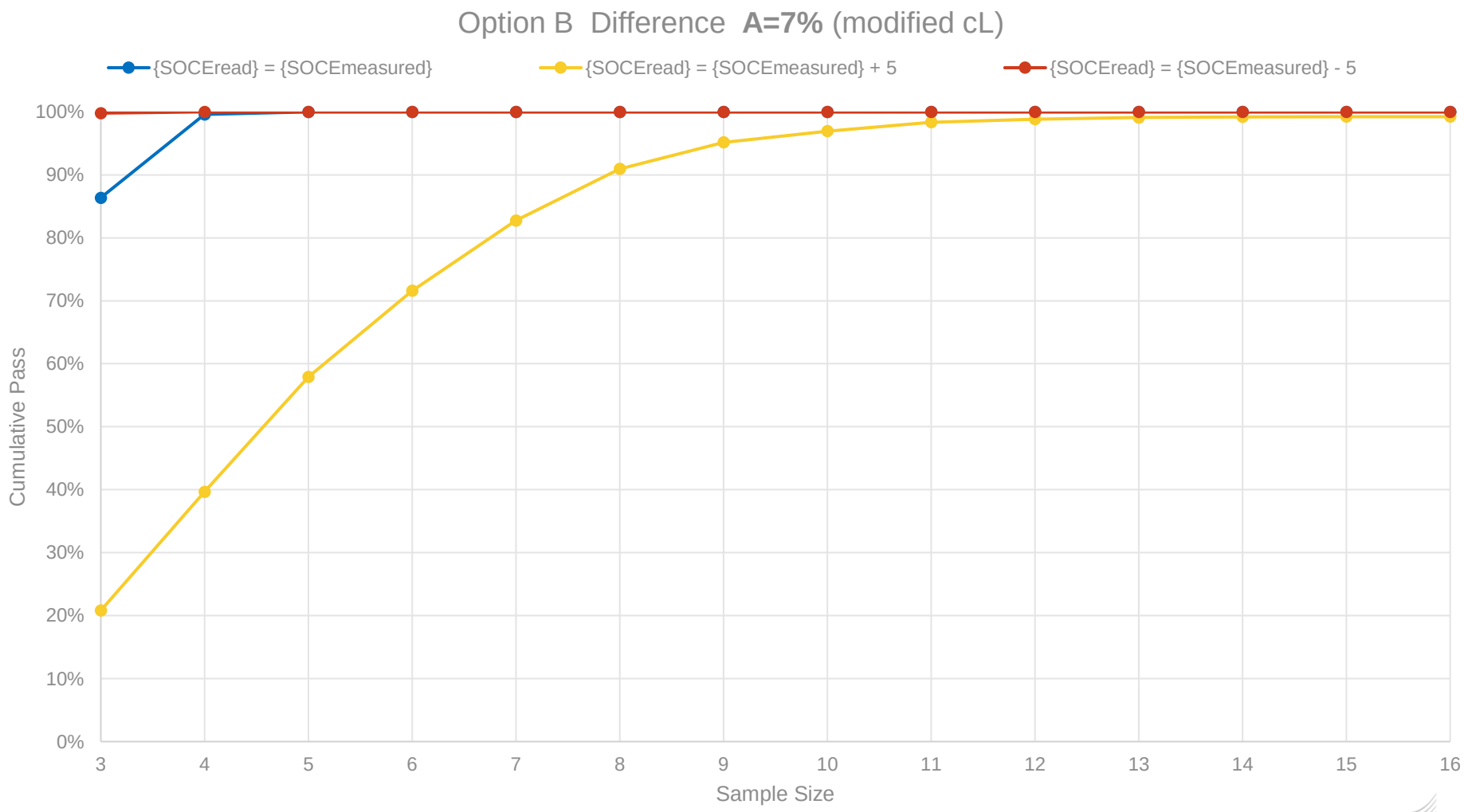
European Commission

soc_{read} shifted above or below the mean value by 5% (modified cL)



European Commission

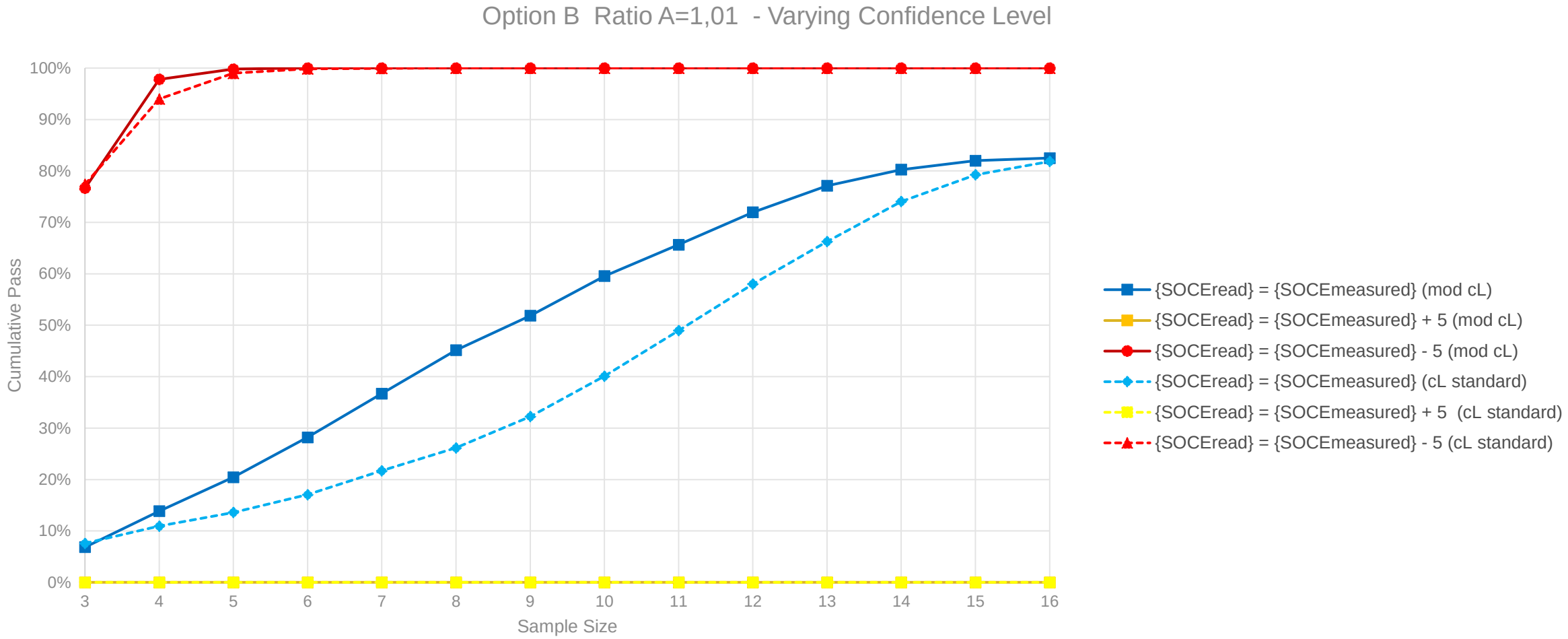
soc_{read} shifted above or below the mean value by 5% (modified cL)



European Commission

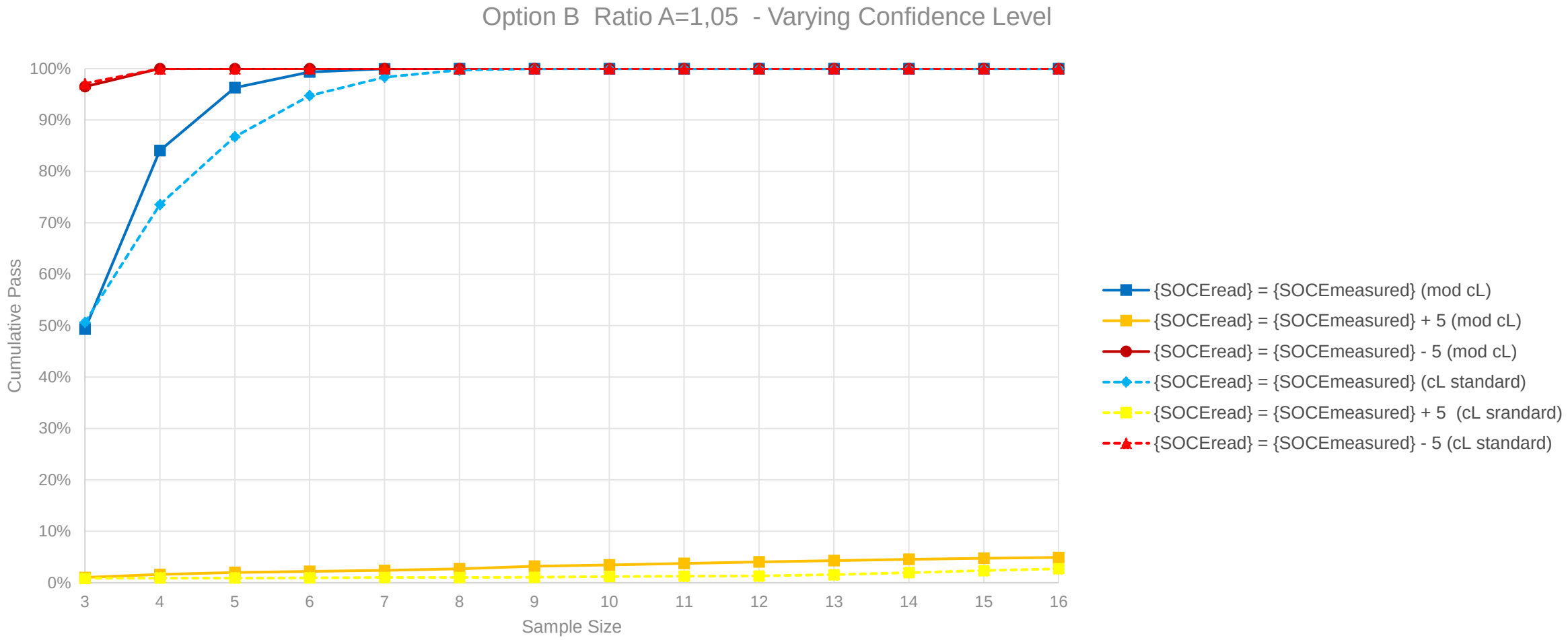
soc_{read} shifted above or below the mean value by 5% (standard cL and modified cL)

- Higher Pass rates for lower sample sizes with decreased confidence level



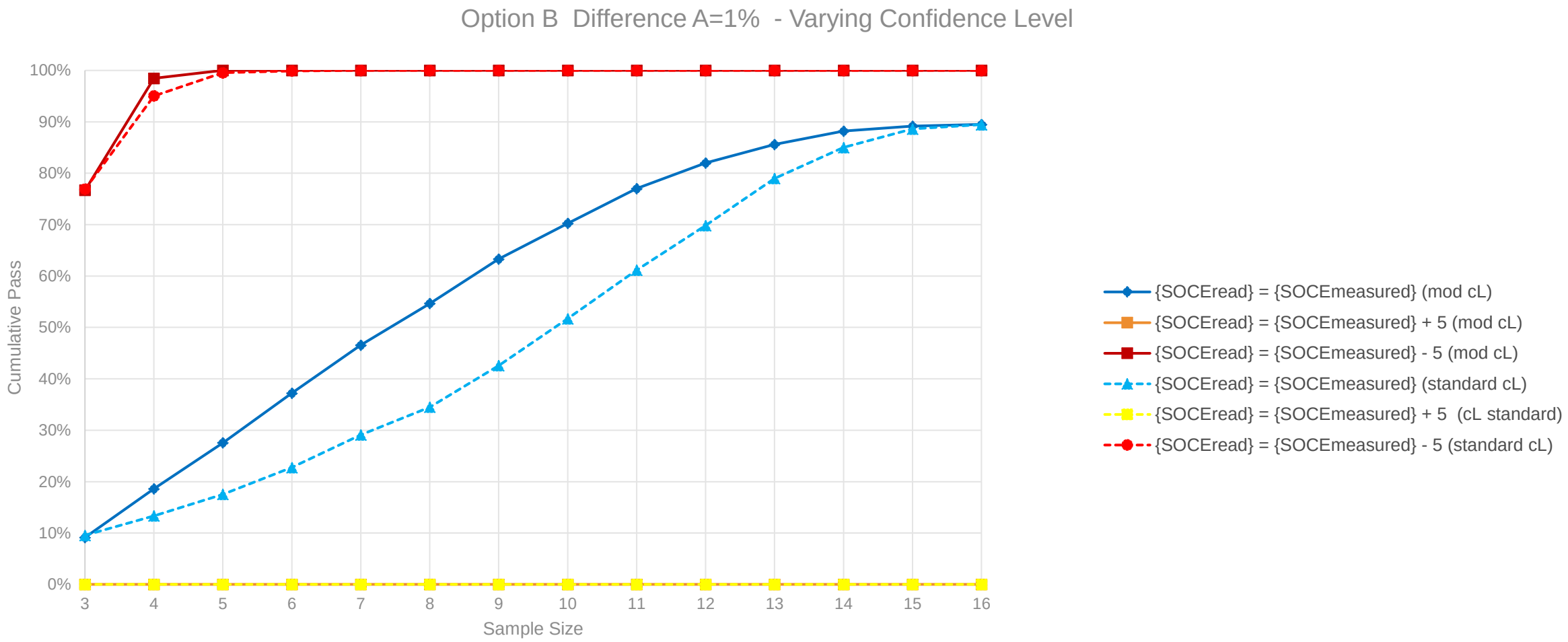
soc_{read} shifted above or below the mean value by 5% (standard cL and modified cL)

- Higher Pass rates for lower sample sizes with decreased confidence level



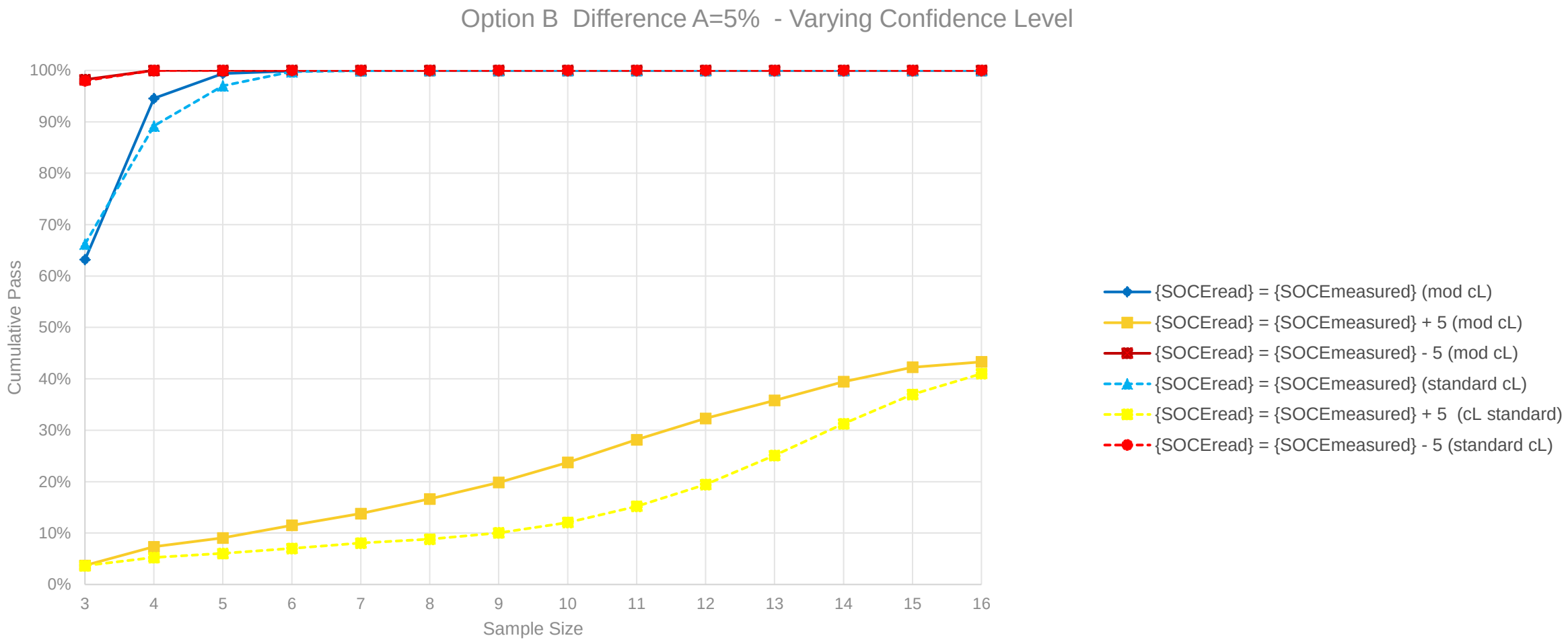
soc_{read} shifted above or below the mean value by 5% (standard cL and modified cL)

- Higher Pass rates for lower sample sizes with decreased confidence level



soc_{read} shifted above or below the mean value by 5% (standard cL and modified cL)

- Higher Pass rates for lower sample sizes with decreased confidence level



Further steps

Outcomes of discussions of May 12th:

- Varying standard deviation on tested distributions
- Multimodal distribution to be tested
- Testing the possibility of decreased accuracy of monitor software with aging

Thank you

Q&A

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