Avoid Data that Hides Behind Error Band

Presented to:

CARB Biodiesel/Renewable Diesel Workgroup

By:

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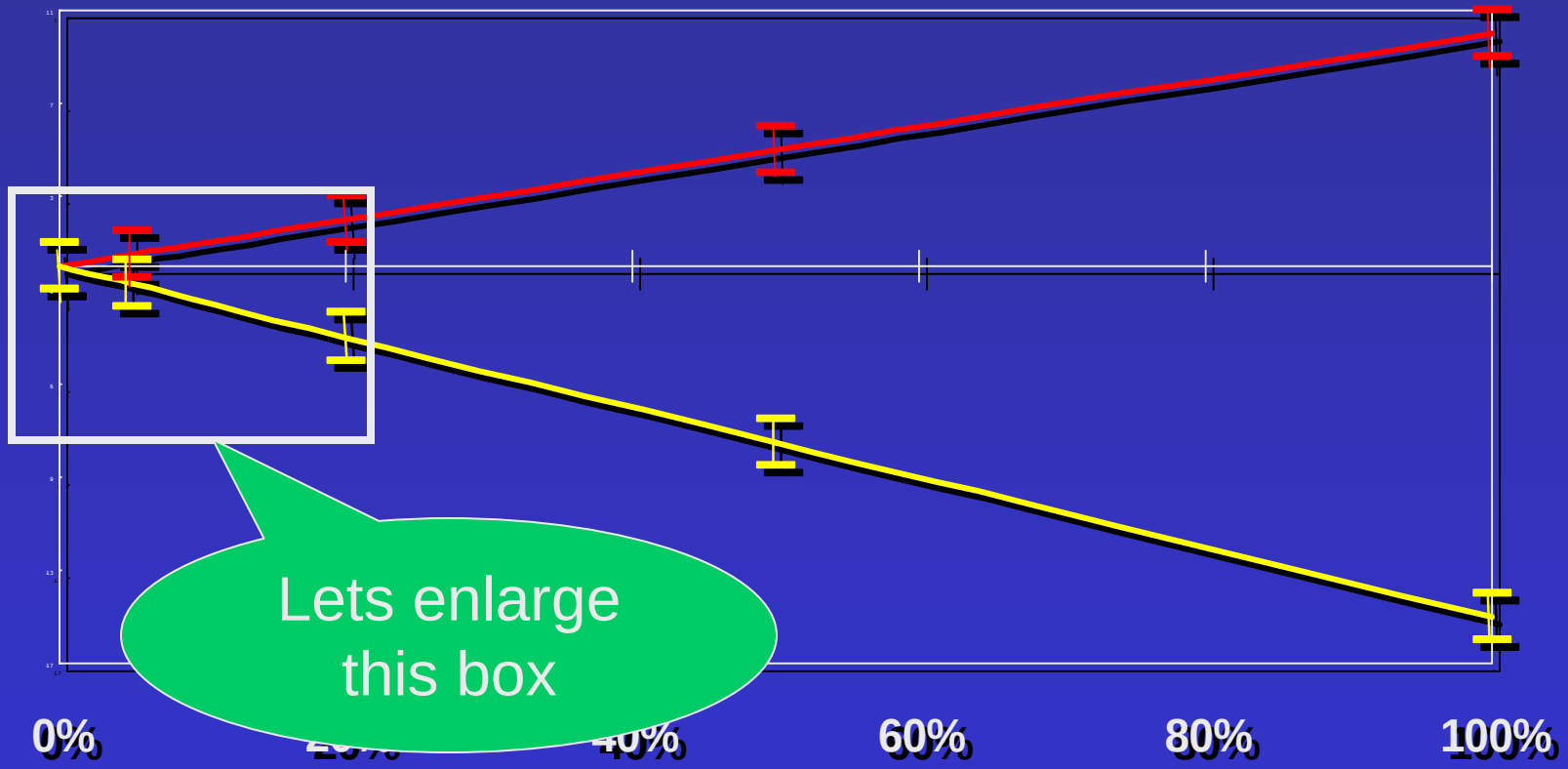
Concern

- Step on a bathroom scale. Do you have enough cash to buy coffee?
  - If you have a pound of money, probably yes!
  - If you only have a few $1's, you can't tell!
- Our ability to measure small emissions differences and the desire to test low concentration ranges are not compatible.
- The next chart assumes a ± 1% error band and illustrates we either have to:
  - Measure more precisely, Or
  - Use greater concentration changes

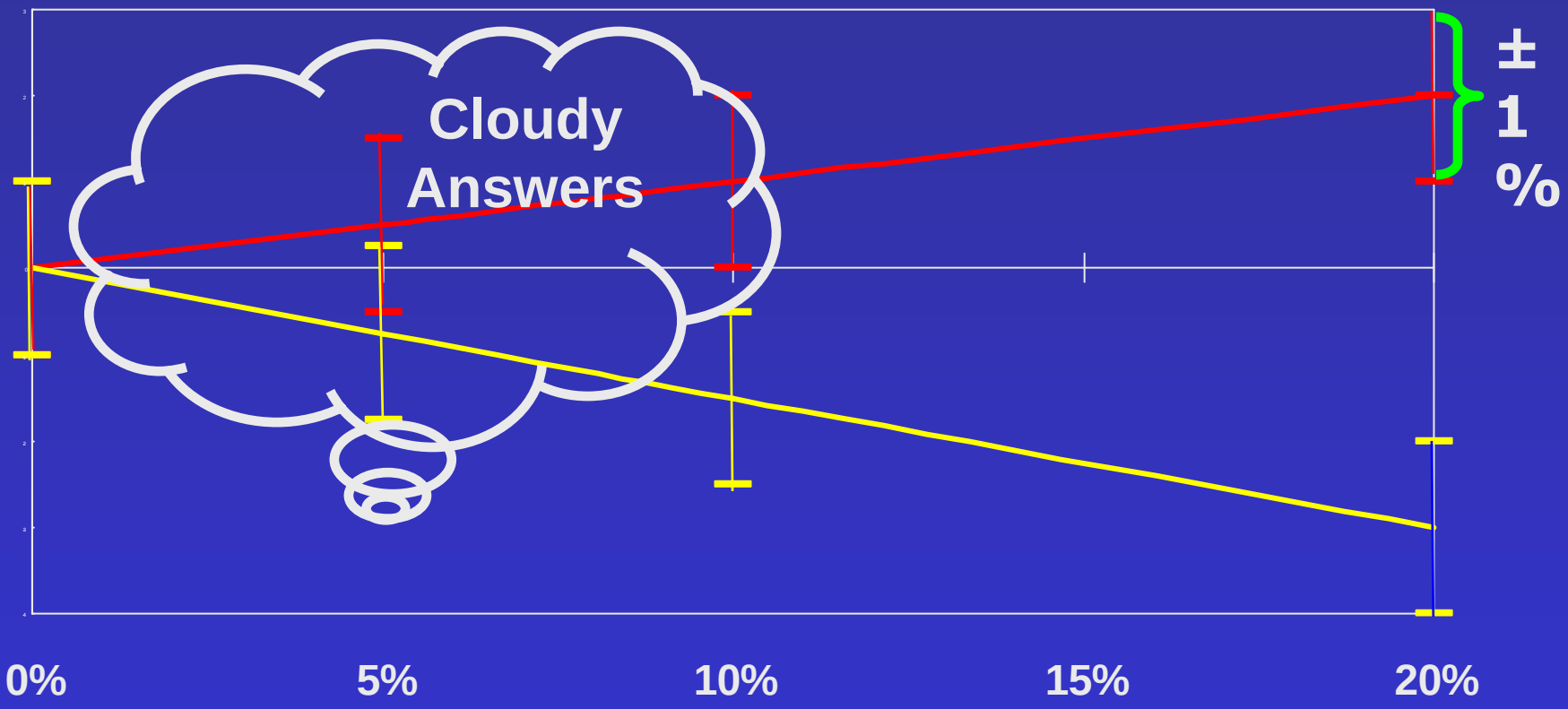
± 1% Error Band Can Create Statistical Insignificance



Remember

- We are measuring differences between two very small numbers.
- To illustrate, I over simplify and assume one pure component increases the difference by 10% and the other decreases it by 15% and that the impact is linear with concentration
- Measuring that difference to ±1% is outstanding.
- For large differences, no problem.
- But, with small differences the error bands overlap
  - Overlapping zero creates statistical insignificance
  - Overlapping product responses means no statistically significant difference in responses
- Now lets look at low concentration range

± 1% Error Band Creates Statistical Insignificance



Observations

- At 5% concentration the +10% change product with a ±1% error band yields a statistically insignificant conclusion.
- The -15% change product with a ±1% error ban also yields a statistically insignificant conclusion at 5% concentration.
- What is even worse is that the error bands overlap each other meaning the experiment showed no statistically significant differences between the products at 5% concentration.
- So how much change do we need to get statistical significance at low concentrations?

Minimum Observed Pure Component Change Required for Statistical Significance

Error Band	±1%	±2%	±3%
5% Concentration	>20	>40	>60
20% Concentration	>5	>10	>15
50% Concentration	>2	>4	>6

Implications

- Obviously we must minimize the error band.
- Unless the biofuels cause very large changes the 5% concentration tests are a waste of money & opportunity.
- Create big question: What do we do with statistically insignificant answers at low concentrations when we have statistically significant results at high concentrations?
  - Do we increase the number of runs?
  - Do we discard the data?
  - Do we allege no impact at low concentrations?
  - Do we use the trend line between significant findings and zero? Or
  - Do we design the experiment to reduce the probability of getting statistically insignificant results?
- Now lets estimate how much change we can expect.

Begin by Estimating the Properties of the Blends

	CARB Base Fuel	5%	10%	20%	50%	Pure Product
Aromatics vol%	20	19	18	16	10	0
Sulfur,ppm	5	5	5	4	3	0
Alkanes Cetane	53	55	57	60.9	72.8	92.5
Esters Cetane	53	53.1	53.2	53.4	54	55
Alkanes SG	0.85	0.85	0.84	0.84	0.82	0.78
Esters SG	0.85	0.85	0.85	0.86	0.87	0.88
Alkanes T50	505	510	514	523	538	552
Esters T50	505	511	519	529	620	649

Relative Impact on Blend Properties

- These properties are inputs to the Texas Commission on Environmental Quality's NOx predicting model.
- Alkanes and Esters have the same impact on sulfur and aromatics concentration.
- Esters have little impact on cetane while alkanes increase cetane significantly.
- Esters and Alkanes have opposite impacts on specific gravity.
- Esters raise T50 more than Alkanes do.

TCEQ Unified Model

- The NOx prediction model was Down loaded from TCEQ's web site.
- It specifically does not apply to ester blends but it is OK for this task.
- All we want to do is see what the diesel property changes imply for NOx emissions.

In TCEQ Unified Model NOx Decreases When:

- Cetane increases
- T50 increases
- Aromatics decrease
- Specific gravity decreases
- Alkane impact is: + + + +
- Ester impact is: o + + -
- Also, model not certified for esters

Estimated % NOx Reduction from Base

	5%	10%	20%	50%	Pure Product (1)
Alkanes	-0.9	-3.1	-5.0	-12.2	-22.6
Esters (2)	-0.5	-0.7	-1.3	-4.6	-6.4

(1) Extrapolated beyond model range
(2) Model not certified for esters

Bottom line: It will be difficult if not impossible to get a statistically significant NOx finding at 5% concentration.

Recommendations

- Run tests at 20, 50 & 100% concentrations before running low concentration blends.
  - Experience should improve our precision
  - We will know if the low-C runs are justified
- Run low concentration tests only if error bands and measured differences justify.
- I have recommended:
  - Neste supply the renewable diesel test fuel.
  - Fund an additional concentration level for the renewable diesel alkanes.
  - That the test matrix be changed to include R20, R50 and R100 runs on the older engine.

Thank you

- If we have time, I will take some questions now.
- But, if you have more later, here are my contact data:

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