A Black Carbon Testing Protocol

Lessons Learned from
Nordic Council and CCAC Projects

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Why Do We Need a BC Testing Protocol?

- Compare stove-to-stove for health (and climate) impacts from BC: What is a good stove? A bad stove? A really good stove that should be promoted?
- These questions can only be answered if we have a standardized means of comparison.
- Many academic labs test ”elemental carbon,” but no widely accepted and practical method for for BC
- Standard protocol needed to establish any BC emission limits, either voluntary (Eco-labelling schemes) or regulatory
- Can contribute to providing improved emission factors for emission inventories

The Beginning: BC Protocol for Nordic Swan

- BC Testing Protocol initially developed in 2014-16 in Nordic Council-funded project aimed at allowing BC standards for next revision of Nordic Swan standards for stoves and boilers (new revision process around 2019
- Developed in cooperation between the three Nordic national laboratories: DTI (Denmark), SINTEF (Norway) and SP (Sweden), with input from University of Eastern Finland and Tami Bond.
- Based on "Norwegian method" ("cold" testing), similar to those of U.S.EPA, using a dilution tunnel to avoid overloading of filters
- BC analyzed as EC (elemental or black carbon), with testing including PM and OC (organic carbon) at Sunset Laboratories (Neth and US)
- Additional "beta-testing" and refinement under current CCAC Domestic Heating project

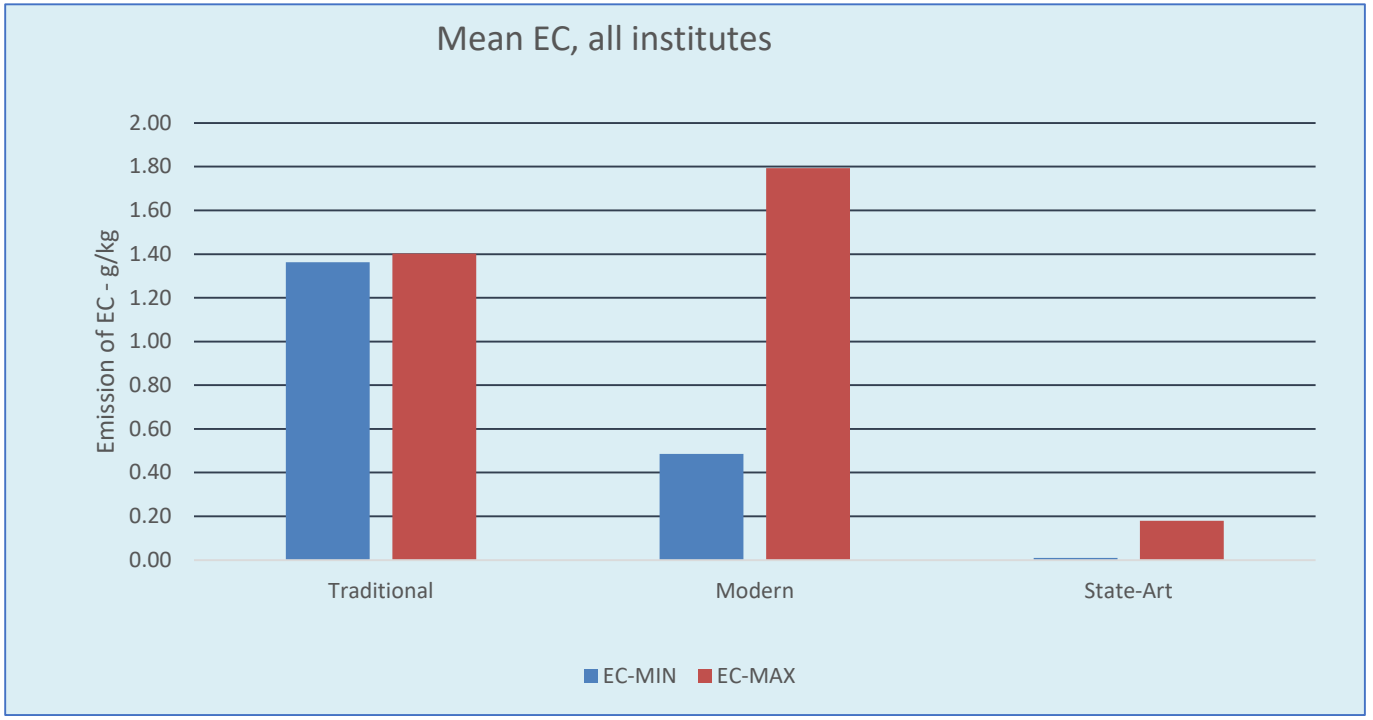
Reference: *A Protocol for Measuring Emissions of Elemental Carbon and Organic Carbon from Residential Wood Burning, TemaNord, 2016:541, Nordic Council of Ministers*

Results from Three Nordic Labs plus Ostrava, Czech Republic (Nordic Council + CCAC Testing):

Comparable Results Between Labs

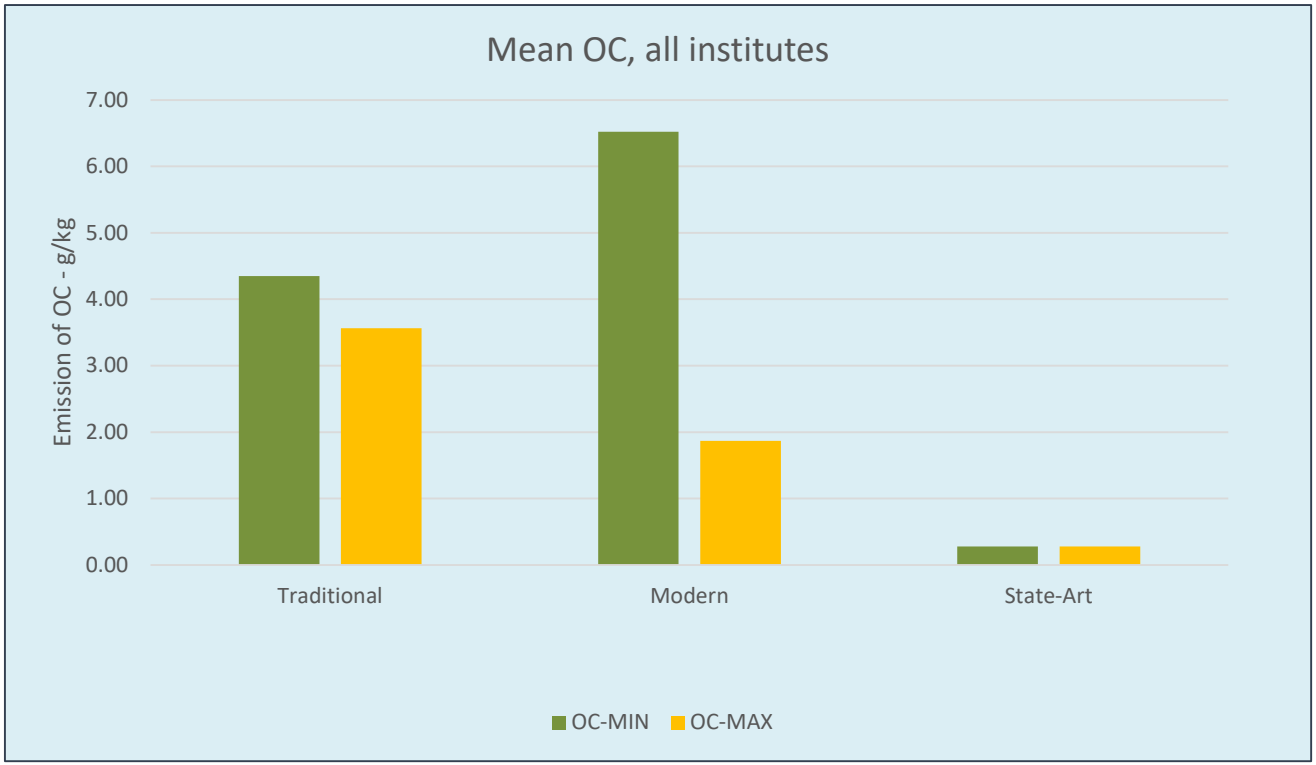
Mean BC (EC) emissions per stove technology class ("state-of-art" is "bionic fire" stove)

MIN is Minimum Heat output (blue) MAX is Maximum heat output (red**)**



Mean OC Emissions, Same Classes (Easy Conclusion: BC does not=OC!)

MIN is Minimum Heat output (green) **MAX is Maximum heat output (yellow)**



Ongoing BC Protocol Beta-testing in Chile (Cerylab) and U.S. (USEPA)

- Chile using local eucalyptus wood fuel; testing one conventional stove common on the Chilean market, and a second reverse combustion, inverted flame stove
- USEPA testing several stoves (also own ongoing project), from very old “dirty” to modern low-emission stoves. Local fuel: oak and spruce
- Both experiences will be useful in showing applicability of BC Protocol to different markets and local stove conditions, as well as unexpected barriers and testing glitches

What About the “European” or “Hot” Testing Method?

- As project add-on, decided to see whether “hot” testing produced similar results as widely deployed in EU countries (EN13240)
- Only tests occur at rated (=“most efficient”) heat output, with flue gas sampling direct in the stack, in the “hot” flue gas and no dilution tunnel.
- Tried at DTI (Denmark) and Ostrava (Czech Rep) only.
- Conclusion #1: can tell a “bad” stove from a “better” stove (same order), but far less differentiation and certainty as misses even more of the “high BC” portions of burn cycle (eg, start-up and cool-down)
- Conclusion#2: For BC rating purposes in Europe, VERY good that Ecodesign process continued to allow the Norwegian method!

Further Development: "GreyScale"

- To cut costs (especially for producers doing trial runs or for less developed country markets), DTI as additional project input developed and tested a "greyscale" method (used for cookstoves, BC sampling on snow, etc.)
- 45 Duplicate filters from Nordic Council and CCAC used to develop a set of pictures with eight colors ranging from Whitish/Pale Grey to pitch Black
- Blind testing: visual matching with "greyscale" color then compared to actual testing results from first filters by Sunset Laboratory
- "Greyscale" worked well to associate with actual laboratory filter test results. Seen as cost-cutting measure, especially during product development and to enable broader adoption globally under conditions of resource constraint (though should not replace actual filter testing for final certification)
- VERY easy to tell a "very good stove" (Bionic Fire nearly white)

Overall Conclusions for BC Testing Protocol

- Results demonstrate that that it is possible to get **comparable results** in different laboratories using the Protocol

- Some spread in data with three factors likely contributing:
  1) test repeatability (no two test runs alike, even with other pollutants);
  2) experience in using the Protocol;
  3) the random element of the effectiveness of the startup sequence

- Perhaps the most significant finding: **the new reverse combustion, inverted flame "bionic fire" has negligible emissions of black carbon,** lower even than those measured from pellet stoves. Not expected with a whole-log stove!