Cookstove Research Update

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United States Environmental Protection Agency

Outline

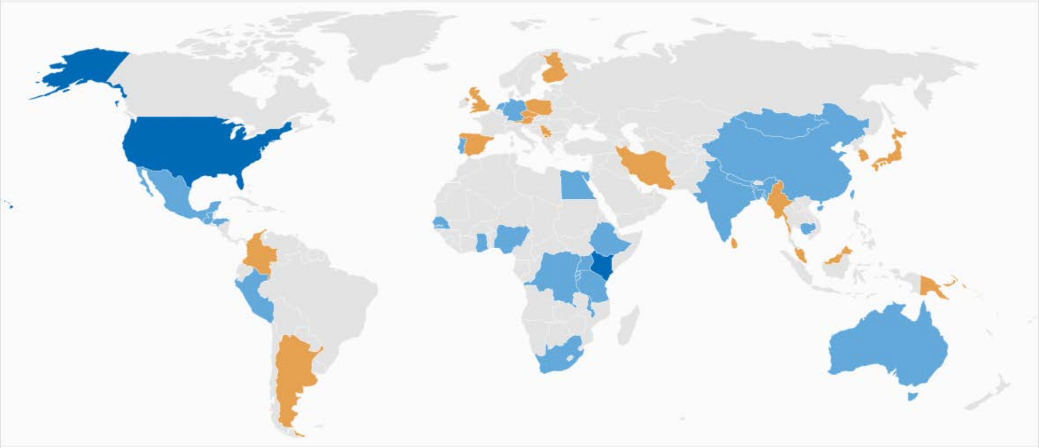
- ISO standards update, *Jim Jetter*
- Capacity building for testing centers, *Jim Jetter*
- Cookstove/fuel test reports, *Jim Jetter*
- PAH (polycyclic aromatic hydrocarbon) emissions, *Guofeng Shen*
- UFP (ultrafine particle) emissions, *Guofeng Shen*
- Questions and discussion

United States Environmental Protection Agency

ISO (International Organization for Standardization)

TC (Technical Committee) 285
Clean Cookstoves and Clean Cooking Solutions
Ranyee Chiang, Chair

- Twin Secretariat
  - ANSI (American National Standards Institute)
  - KEBS (Kenya Bureau of Standards)
- 29 participating member countries
- 16 observing member countries



ISO TC 285

- –Working Group 1 – Conceptual Framework
- –Working Group 2 – Laboratory Testing
- –Working Group 3 – Field Testing
- –Working Group 4 – Social Impact Assessment
- –Task Group 1 – Communications
- –Task Group 2 – Fuels
- –Task Group 3 – Title and Scope

ISO Lab and Field Testing Protocols

- **Based on**
  - –Best practices from existing protocols
  - –Knowledge/experience of Working Group experts
  - –Methodology in related sectors
- **Trade-offs**
  - –Cost
  - –Reflection of actual use
  - –Statistical power

BEST PRACTICES from existing protocols

	China	India	HTP	CSI-Indo	WBT	IWA
3 cooking power levels			✓	✓		
2 cooking power levels					✓	✓
1 cooking power level	✓	✓				
Efficiency	✓	✓	✓	✓	✓	✓
PM (particulate matter), gravimetric (filter) method	✓	✓		✓	✓	✓
CO (carbon monoxide)	✓	✓	✓	✓	✓	✓
Emissions factors based on useful energy ($MJ_{delivered}$)	✓	✓	✓	✓	✓	✓
Emission rates (per time)					✓	✓

Cookstove Testing

Laboratory Testing

Photo credit: Agnes Naluwagga, CREEC (Centre for Research in Energy and Energy Conservation)

Field Testing

Photo credit: Michael Johnson, Berkeley Air Monitoring Group

Cookstove Testing

Laboratory Testing
- Lower cost
  ($1,000 to $8,000)
- More control of variables
- Less variable results
- Stationary equipment
- Less reflective of use

Field Testing
- Higher cost
  ($10,000 to >$100,000)
- Less control of variables
- More variable results
- Portable equipment
- More reflective of use

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Driving Technology Improvement

Laboratory and field testing provides information and incentives for:

- Technology developers
- Manufacturers
- Distributors
- Consumers
- Governments and regulators
- Research institutes
- Donors

Relevance for Stakeholders

- Greater alignment in methodology and metrics around the world
- Adaptation of methodology and metrics to the wide variety of cookstoves, fuels, and cooking practices
- Stakeholders may:
  - Adopt the standard or portions of the standard
  - Adapt the standard to meet needs
  - Participate in further development of the standard

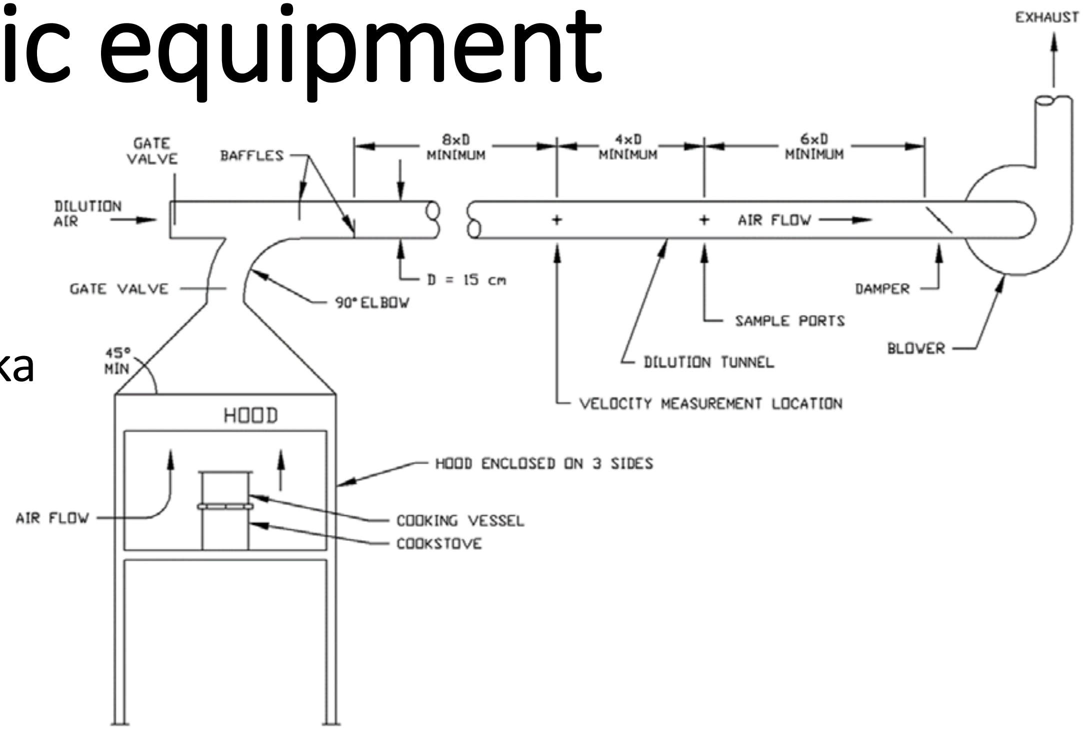
Capacity Building – Regional Testing Centers

Kampala, Uganda

La Paz, Bolivia

Kathmandu, Nepal

RTKCs that have dilution tunnel and gravimetric equipment



- Zamorano, Honduras
- CREEC, Uganda
- CERER, Senegal
- University of Nigeria, Nsukka
- CSIR, Ghana
- KIRDI, Kenya
- CRT/N and RETS, Nepal
- GERES, Cambodia
- IIT-Delhi, India
- G-BEL (Institute of Technology Cambodia), Cambodia
- Beijing University of Chemical Technology, China
- Universidad Mayor de San Andrés, Bolivia
- Peru? Others?
- Aprovecho, CSU, EPA, LBNL, and others in U.S.

Recent EPA Reports – Emissions and Fuel Efficiency

BioLite HomeStove

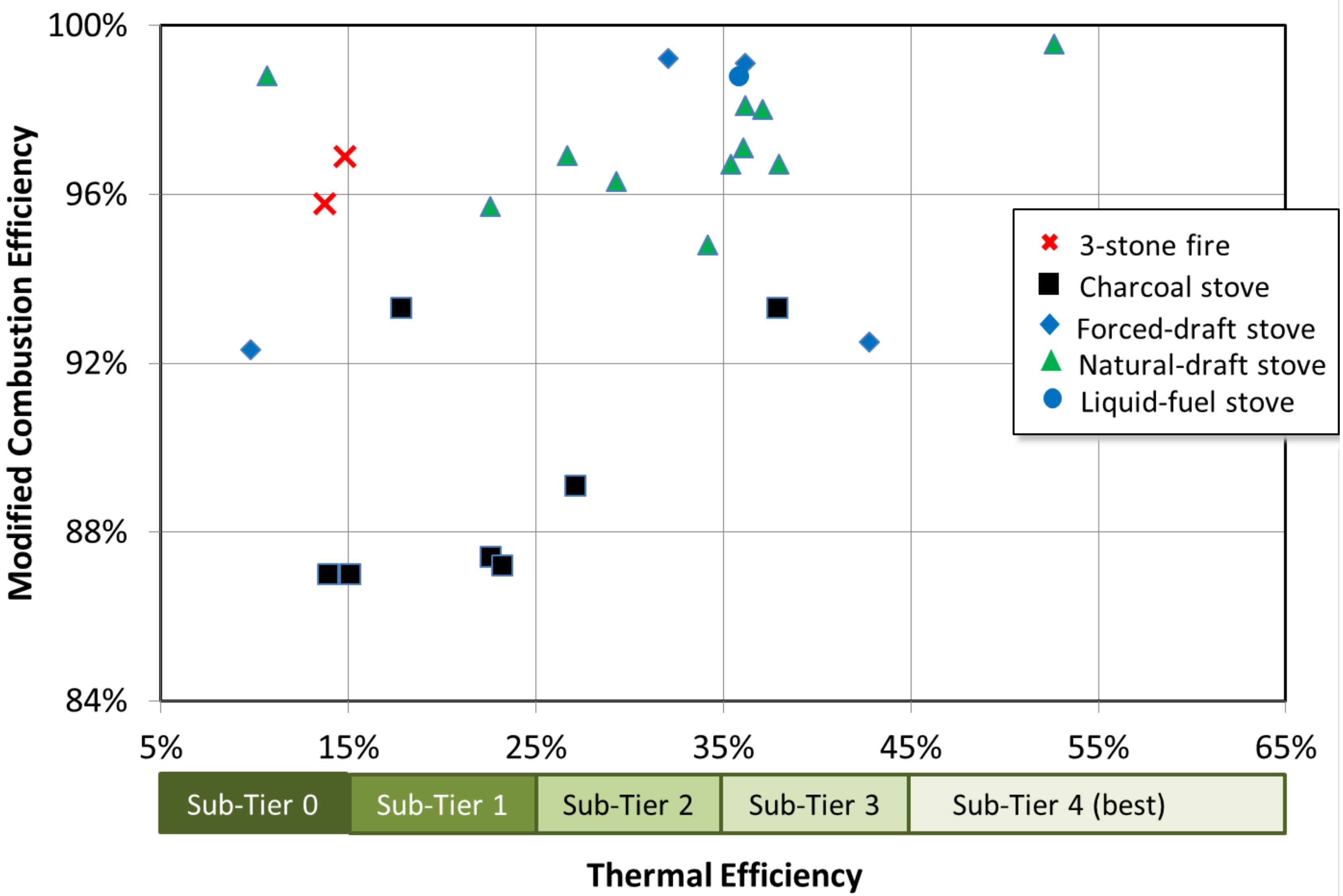
CleanCook Model A1

InStove 60-Liter

Ecocina

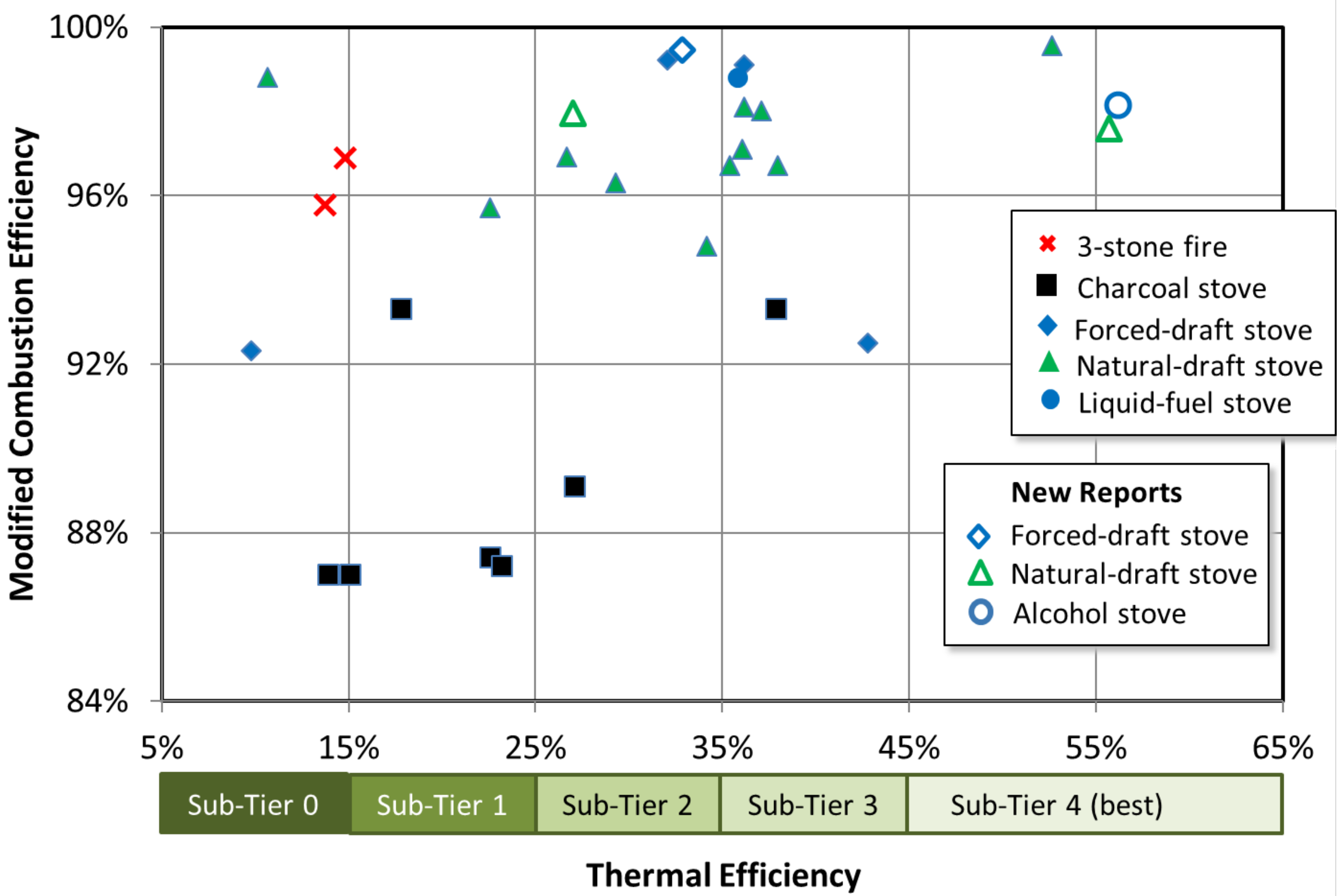
Available at: https://cfpub.epa.gov/si/

Efficiency – EPA *ES&T** results

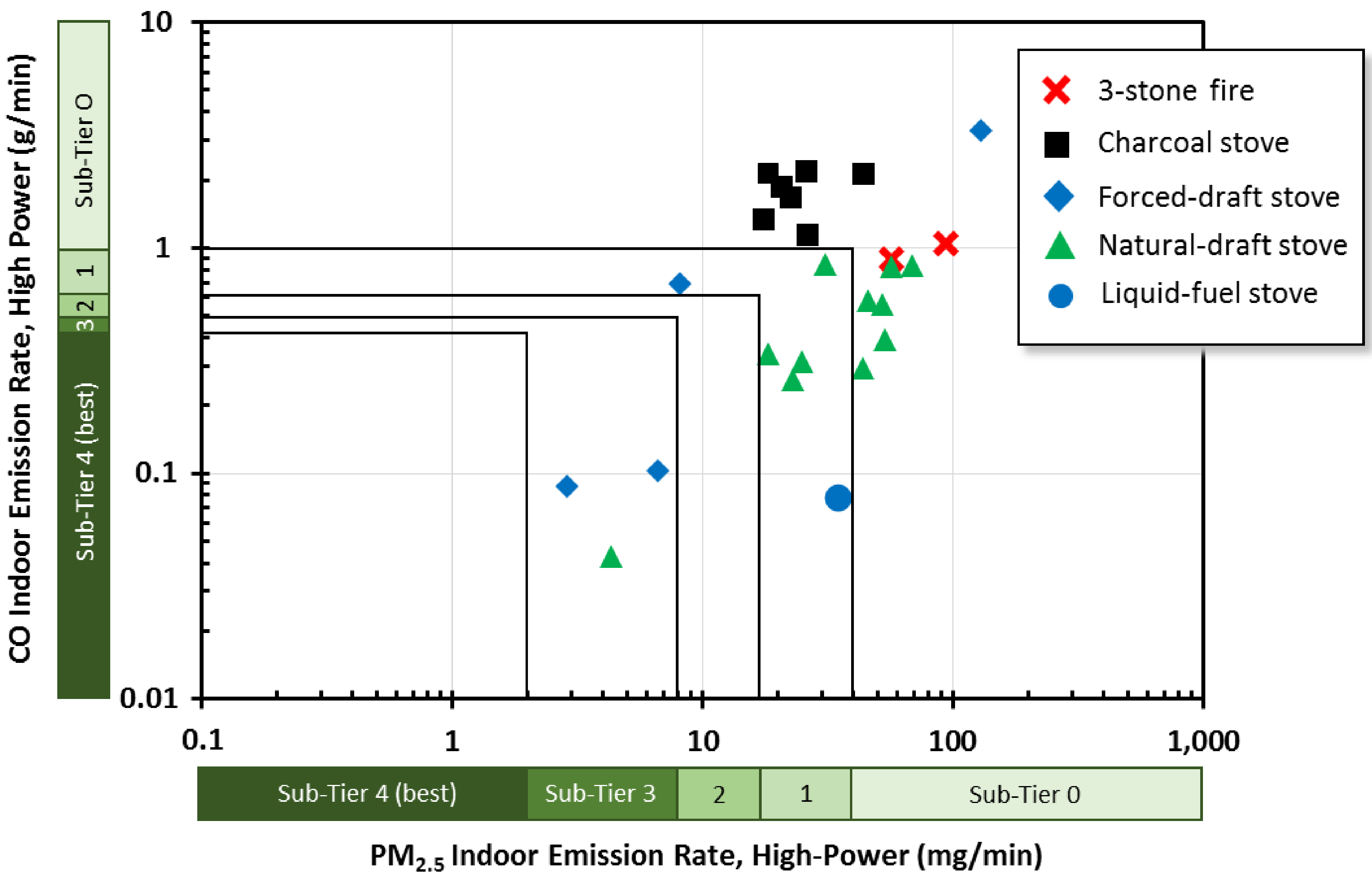


* http://pubs.acs.org/doi/abs/10.1021/es301693f

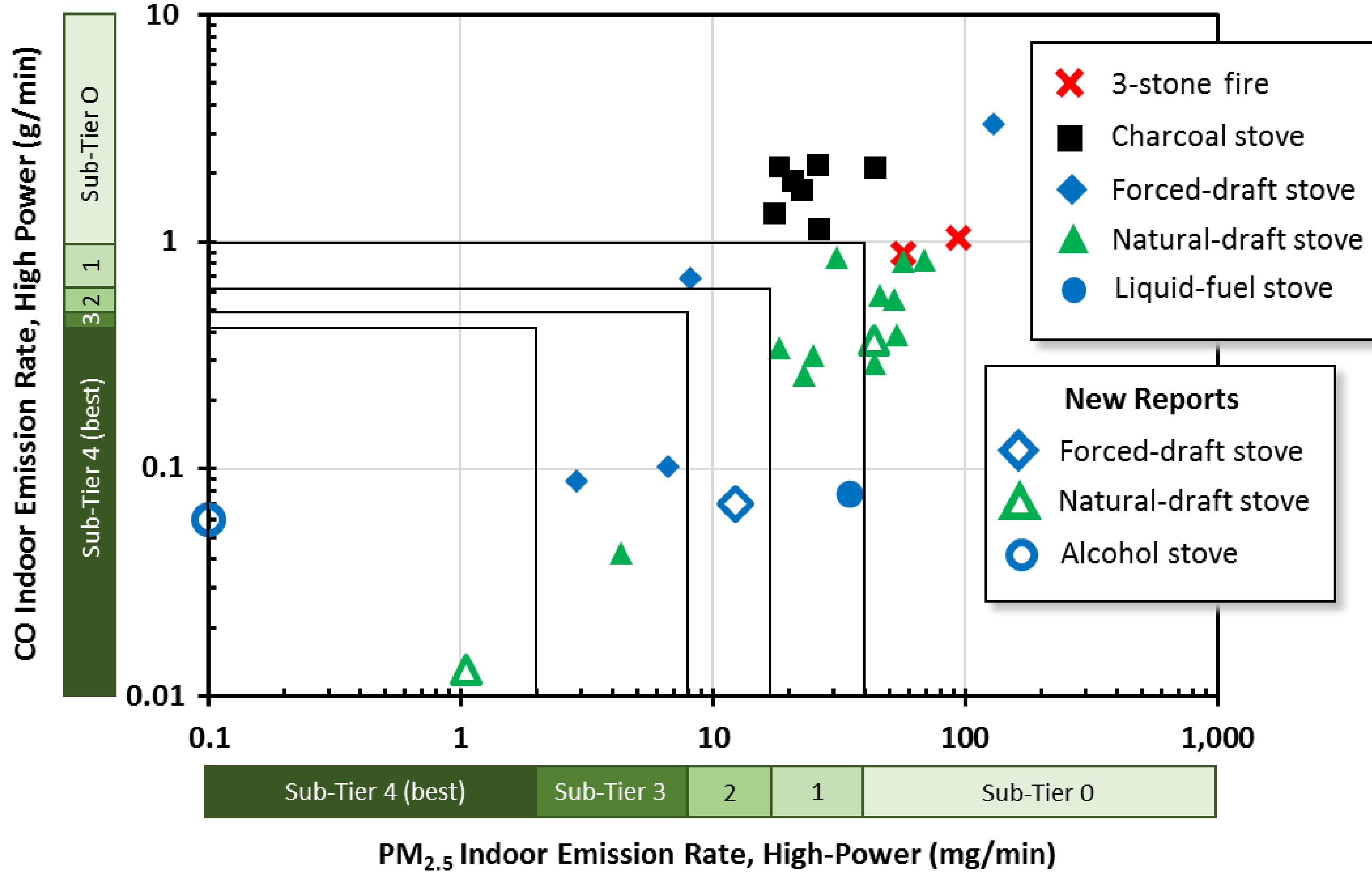
Efficiency – new report results



Emission Rates – EPA *ES&T* results

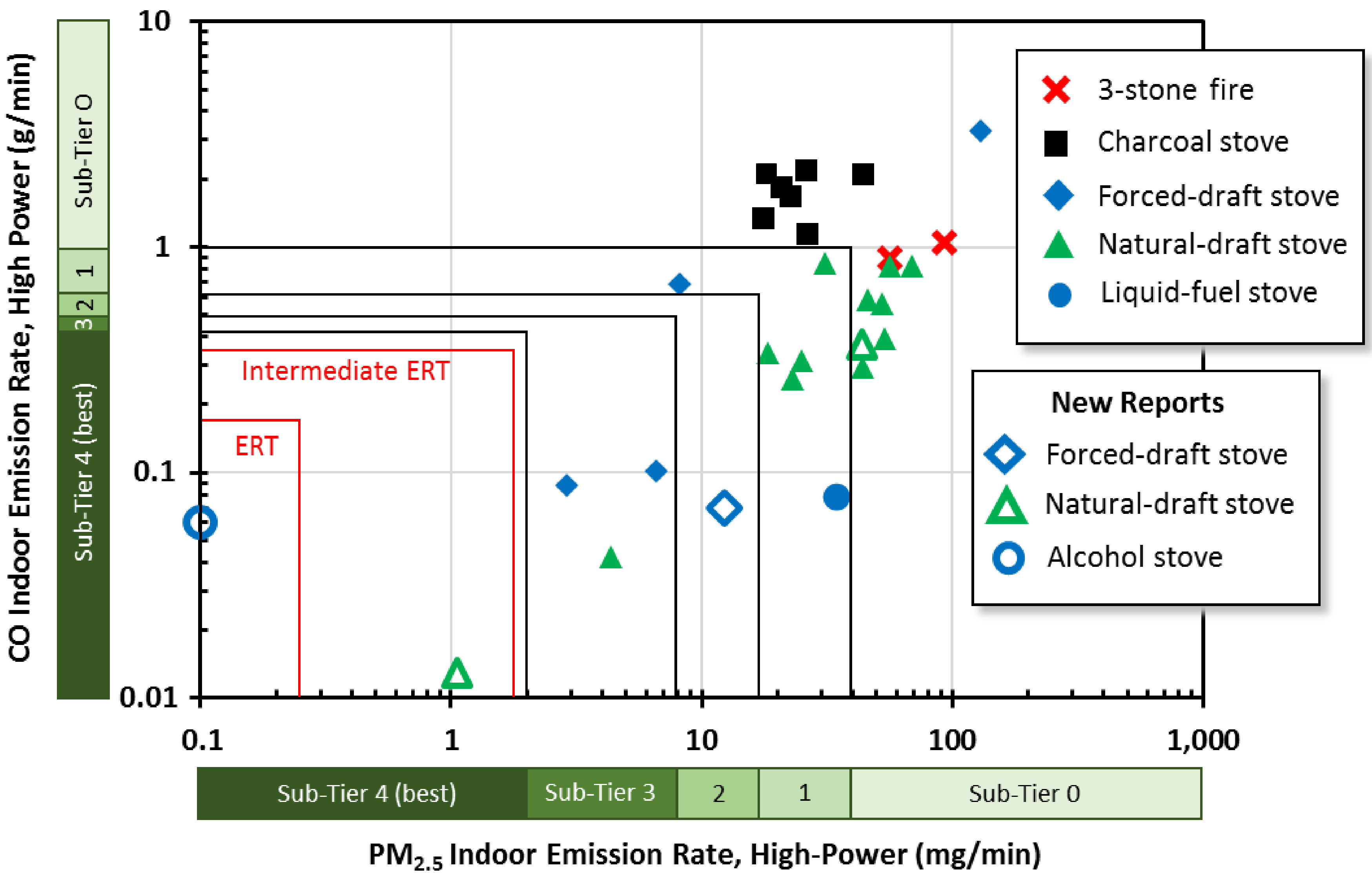


Emission Rates – new reports



WHO Emission Rate Targets (ERTs)

Unvented (no chimney)

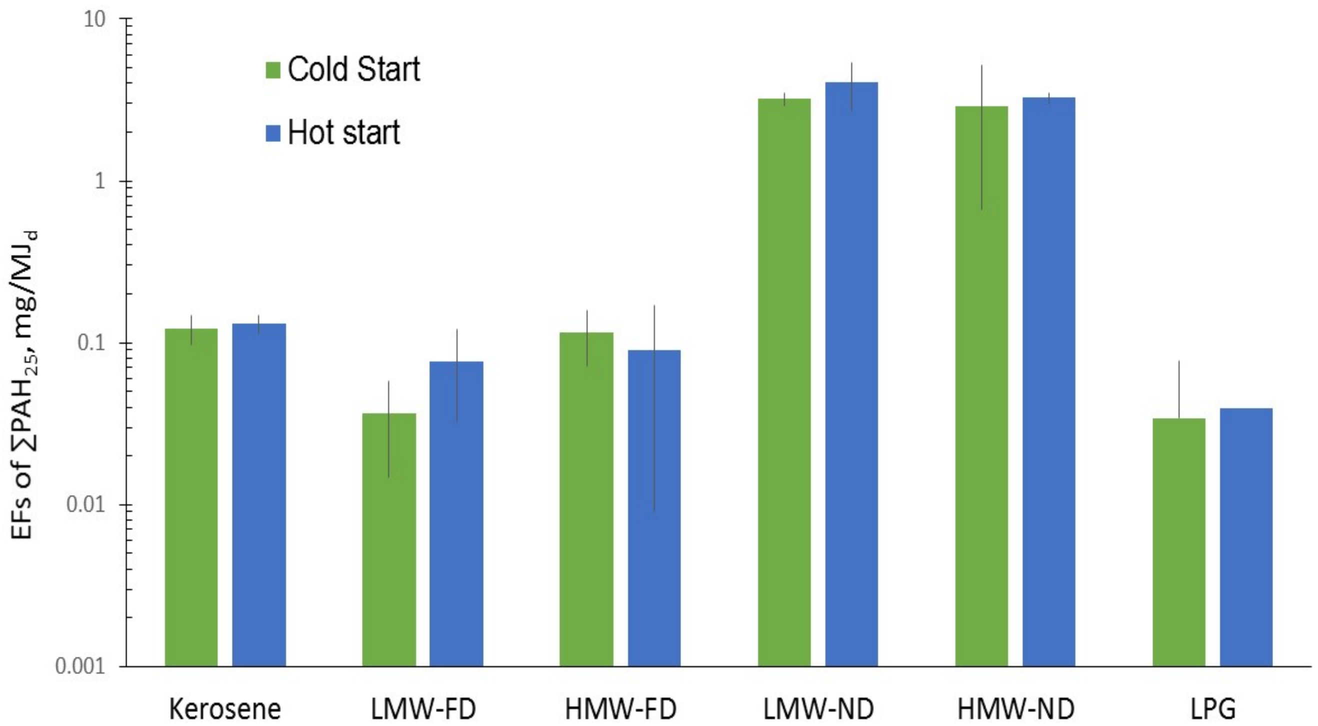


Particulate PAHs (polycyclic aromatic hydrocarbons) Study

- Particulate PAHs emissions from kerosene, LPG, and wood (red oak) burning
- Woodstove: Natural- and Forced-draft stoves
- Wood: High (~30%) and low moisture (~10%)
- Testing protocol: 3-phase Water Boiling Test (WBT)
- Quality Assurance: Regular calibration checks and carbon balance check



Total PAH emission factors



- Highest for Wood-NDS, Lowest for LPG
- Comparable to literature data (kerosene and Wood-NDS)
- Wood-FDS was about 8 times lower than average means for Wood-NDS in literature

- Similar between cold and hot start test phases
- Similar between high and low moisture woods: **Nonlinear impacts & limitation of two levels**

PAHs/$PM_{2.5}$

	High-power phase, cold start	High-power phase, hot start	Low-power simmering phase
Kerosene	10.4±4.4	9.86±2.76	9.15±5.44
LMW-FD	0.960±0.579	1.86±1.00	2.81±1.85
HMW-FD	1.53±0.67	0.732±0.670	[no test]
LMW-ND	7.43±0.67	7.38±2.21	1.28±0.49
HMW-ND	5.73±4.19	7.59±1.20	1.23±0.22
LPG	4.42±4.75	8.10	10.6±2.6

- High in kerosene burning, and low for the wood burning in FDS
- Note the absolute mass of particulate PAHs was low for kerosene and LPG

Conclusion/implications

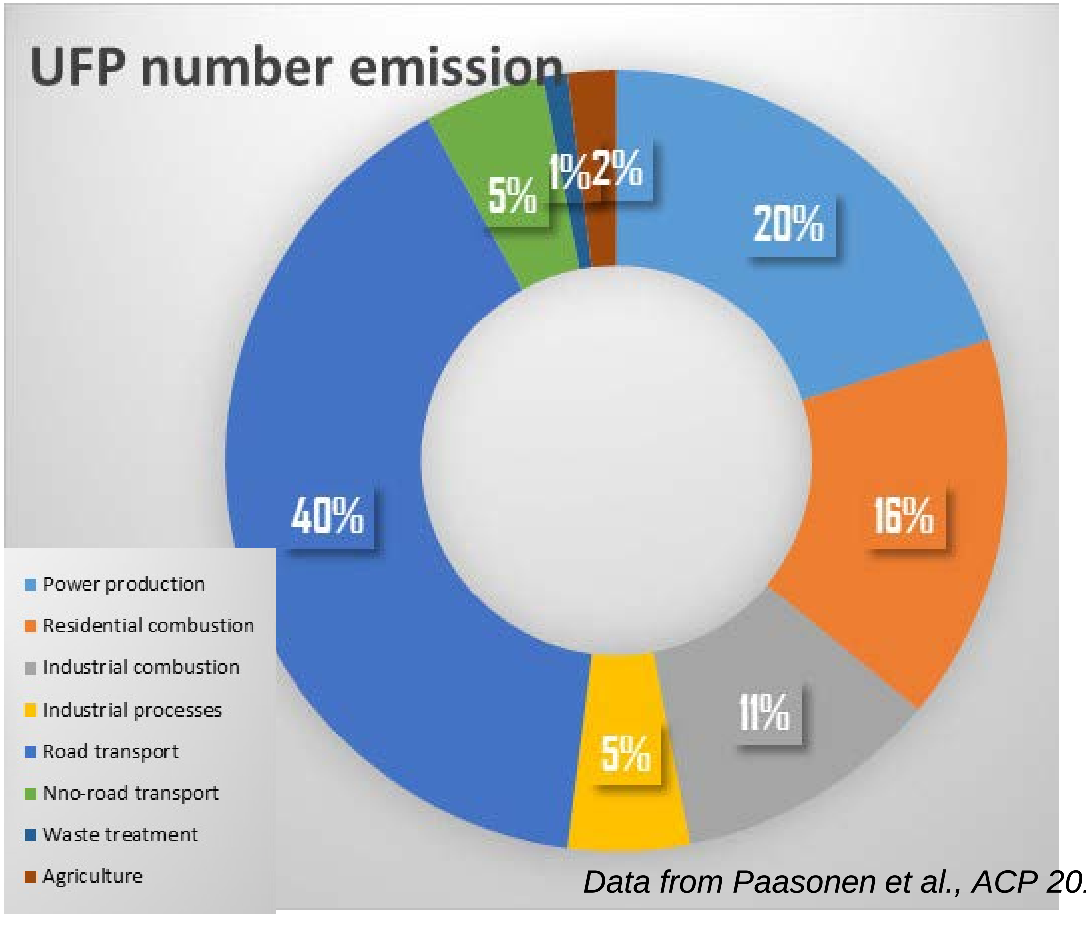
- Higher PAHs emissions from wood combustions, and low in kerosene and LPG burning
- Mass percentages of PAHs in $PM_{2.5}$ were high for kerosene, suggesting higher health impacts due to PAHs exposure, on the basis of per unit mass of $PM_{2.5}$.

Notes on limitation and future works

- Inclusion of gaseous emissions
- Influence of wood moisture-multipoint levels
- various fuel-stove combinations, especially clean ones

Polycyclic aromatic hydrocarbons in fine particulate matter emitted from burning kerosene, liquid petroleum gas, and wood fuels in household cookstoves.
Shen G, Preston W, Ebersviller SM, Williams C, Faircloth JW, Jetter JJ, Hays MD.
Energy & Fuels 31, 2017. http://pubs.acs.org/doi/abs/10.1021/acs.energyfuels.6b02641

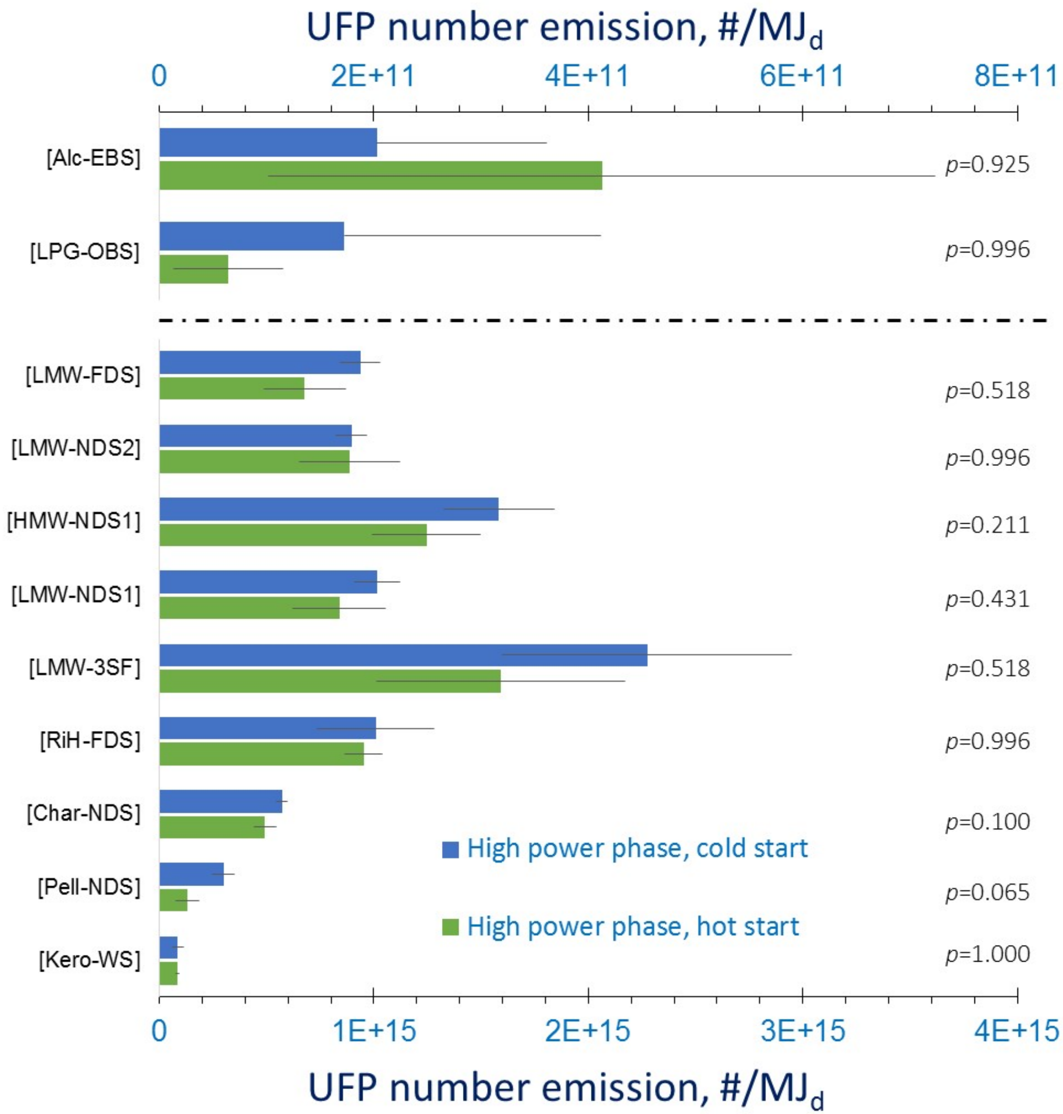
UFP (ultrafine particle) emission study



Data from Paasonen et al., ACP 2016, 6823-40

- 11 Different fuel-stove combinations, including LPG, kerosene, alcohol, pellet and wood burnt in different stove technologies, e.g. natural- and forced-draft stoves
- Testing protocol: 3-phase Water Boiling Test (WBT)

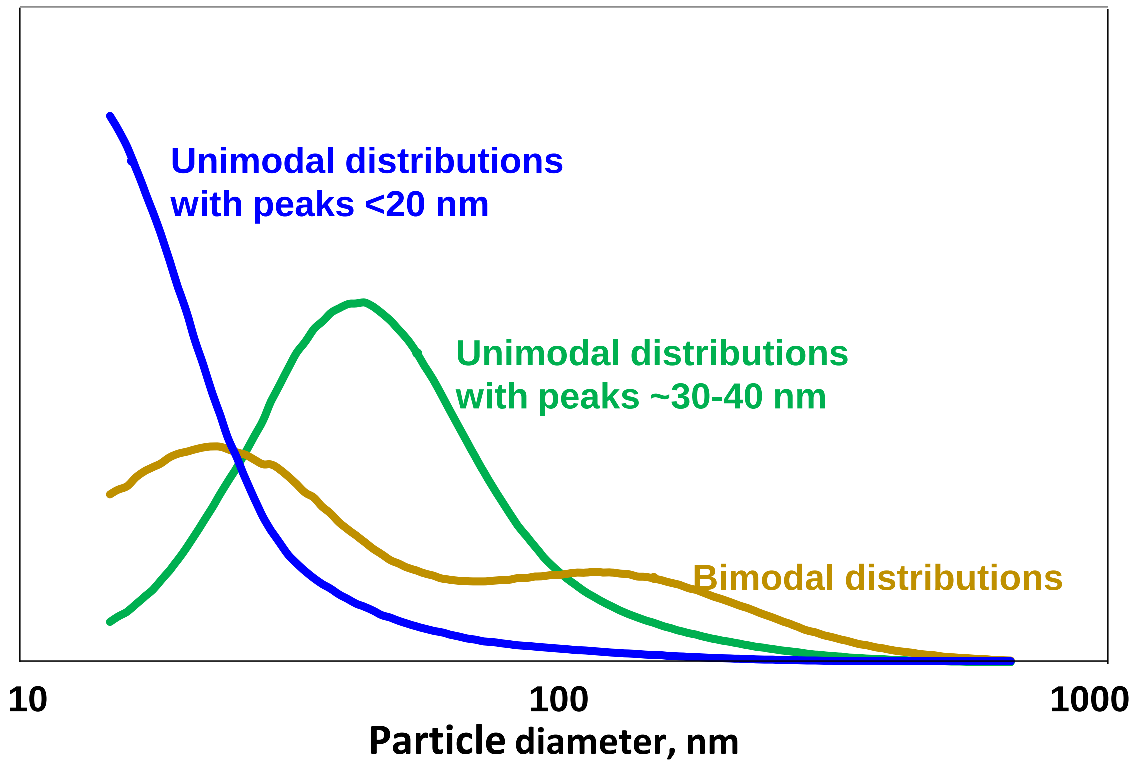
UFP number emissions



Particles/useful energy delivered:

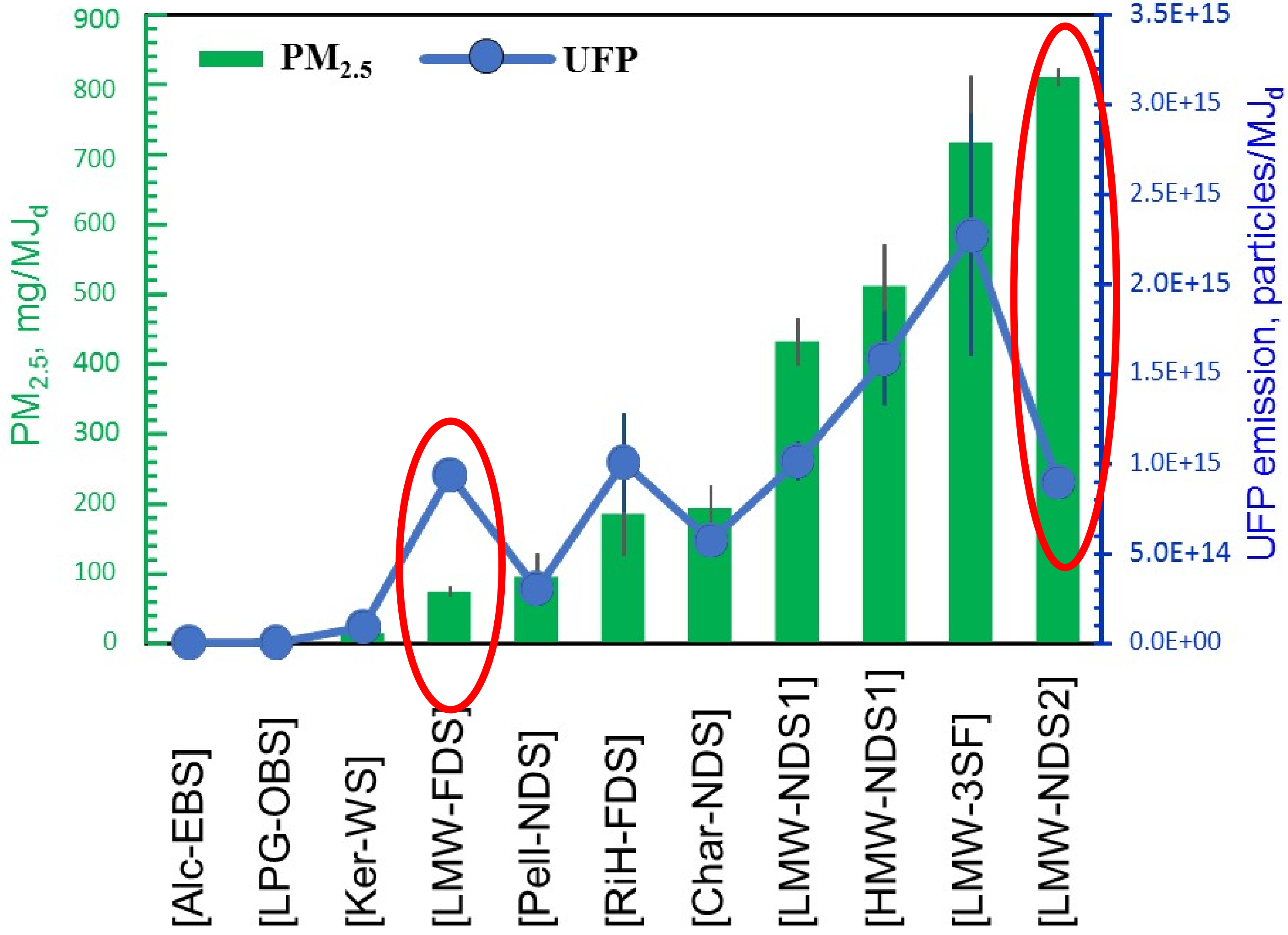
- LPG and Alcohol: ~10^{11}
- Kerosene: ~10^{13}
- Pellets and charcoal:~10^{14}
- Rice hulls and wood: ~10^{15}

UFP Number Size Distribution

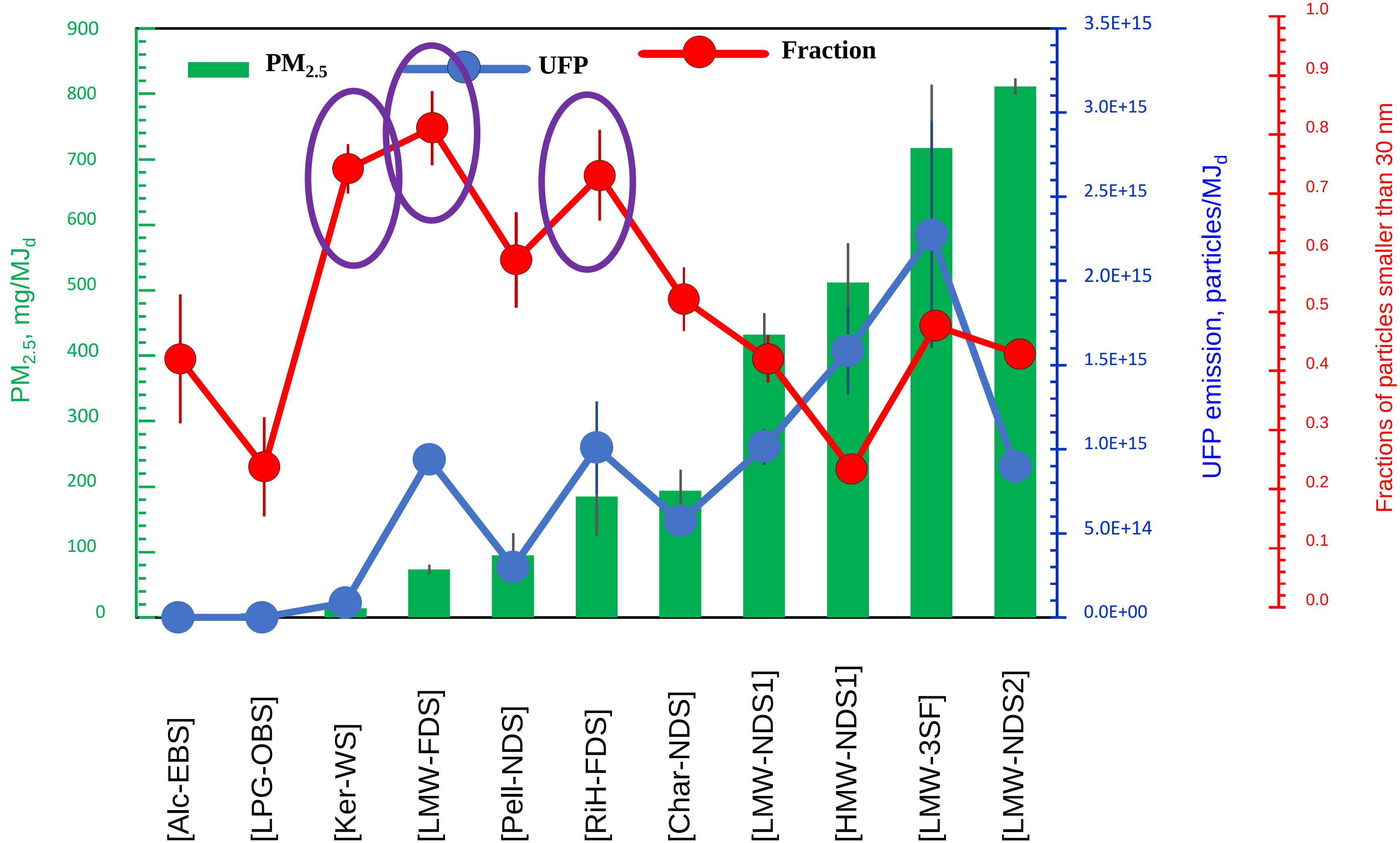


- a unimodal nuclei mode distribution with a less than 20 nm maxima 【LMW-FDS, RiH-FDS, Pell-NDS, Kero-WS, Alc-EBS】
- a unimodal distribution with a ~30-40 nm nucleation mode peak 【HMW-NDS1, LMW-NDS1, LMW-3SF, Char-NDS】
- a bimodal distribution with a major nucleation mode peak at ~20 nm and a smaller second peak at ~80-100 nm 【LMW-NDS2, LPG-OBS】

UFP, $PM_{2.5}$, and fractions of the finest particles



UFP, $PM_{2.5}$, and fractions of the finest particles



Conclusion/implications

- UFPs have significant impacts on air quality, human health and climate
- Residential combustion is one important source of UFP, but few emission characterization studies on cookstoves
- UFP number emission factors were from 10^{11} to 10^{15} #/MJ_d, with low values for clean fuels like LPG
- Size distributions are different among fuel-stove combinations. More attentions to those having low total number emissions but higher fractions of finest particles.

Notes on limitation and future works

- Different stove technologies and burning conditions
- Temporal change of UFP during the combustion process and influencing factors

A laboratory comparison of emission factors, number size distributions, and morphology of ultrafine particles from 11 different household cookstove-fuel systems.
Shen G, Gaddam CK, Ebersviller SM, Vander Wal RL, Williams C, Faircloth JW, Jetter JJ, Hays MD.
Environmental Science & Technology 51. 2017. http://pubs.acs.org/doi/10.1021/acs.est.6b05928

Summary

- Leadership in development of ISO laboratory testing standard
- Capacity building of Regional Testing Centers
- Testing of cookstoves/fuels – efficiency and emissions
- Evaluation of particulate PAH emissions
- Characterization of UFP emissions