

# Black carbon sources & mitigation

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# Rapid mitigation strategy

## *Arctic mitigation*

- ❑ **Goal:** Reduce warming & melting
- ❑ **Target:** Known sources of black carbon deposition to the Arctic
- ❑ **Result:** More pristine snow & ice

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## *Atmospheric mitigation*

- ❑ **Goal:** Rapidly reduce atmospheric warming
- ❑ **Target:** Short-lived species that warm the global atmosphere
- ❑ **Result:** Less heat transported to the Arctic



# Approximate benefit

## 100 Gg/year reduction in black carbon

- ✦ Reduces atmospheric forcing by
  - $\sim 5 \text{ mW/m}^2$
  - Equivalent to  $\sim 0.3 \text{ ppm CO}_2$  (15% of present-day annual increase)

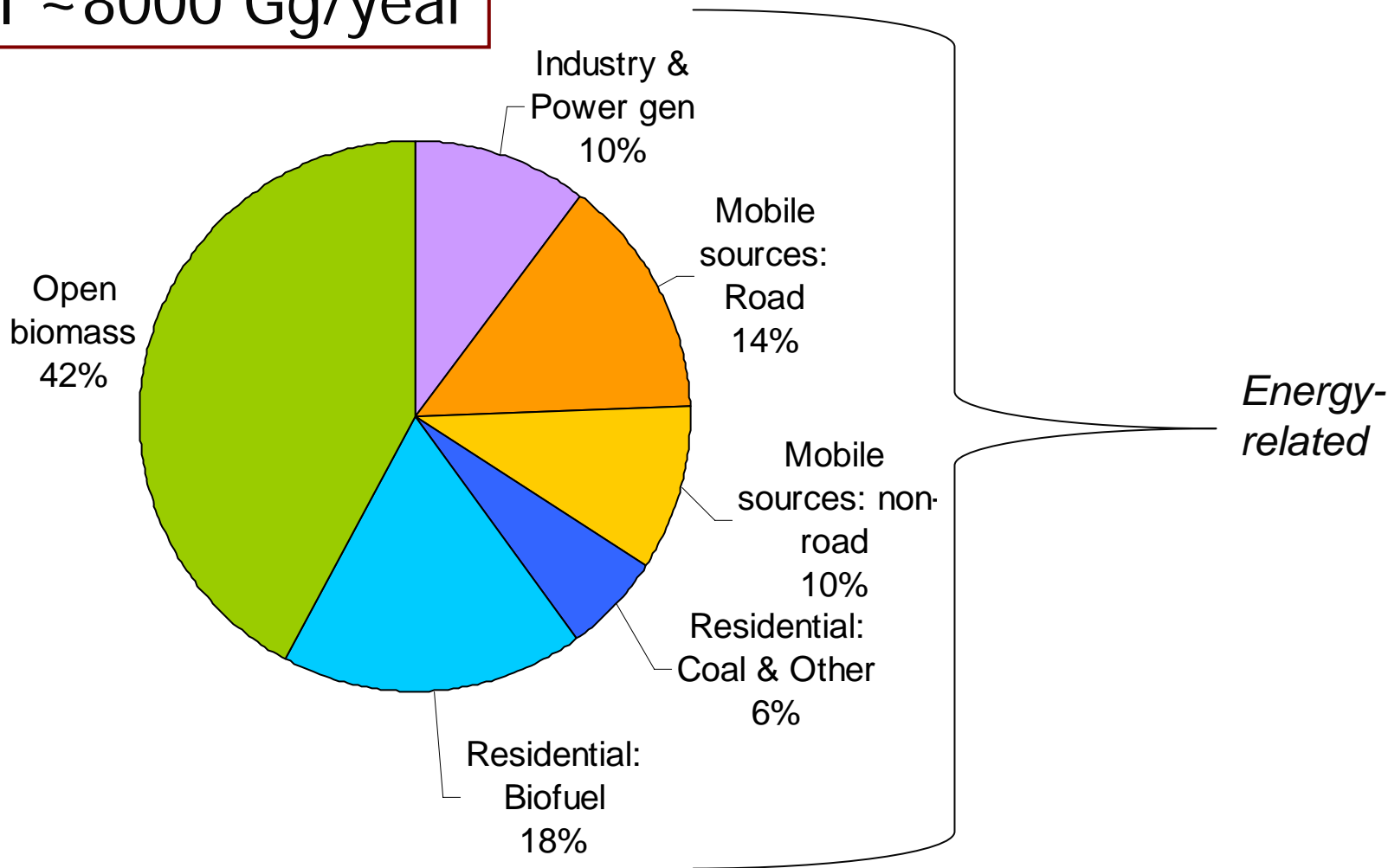
## Arctic input regions (N of 45°)

- ✦ If emissions would have deposited on snow or ice
  - Reduced warming  $\sim$  same size as atmospheric forcing (i.e. double benefit)
  - Some regions may have relatively greater effect



# Emissions of black carbon by source type

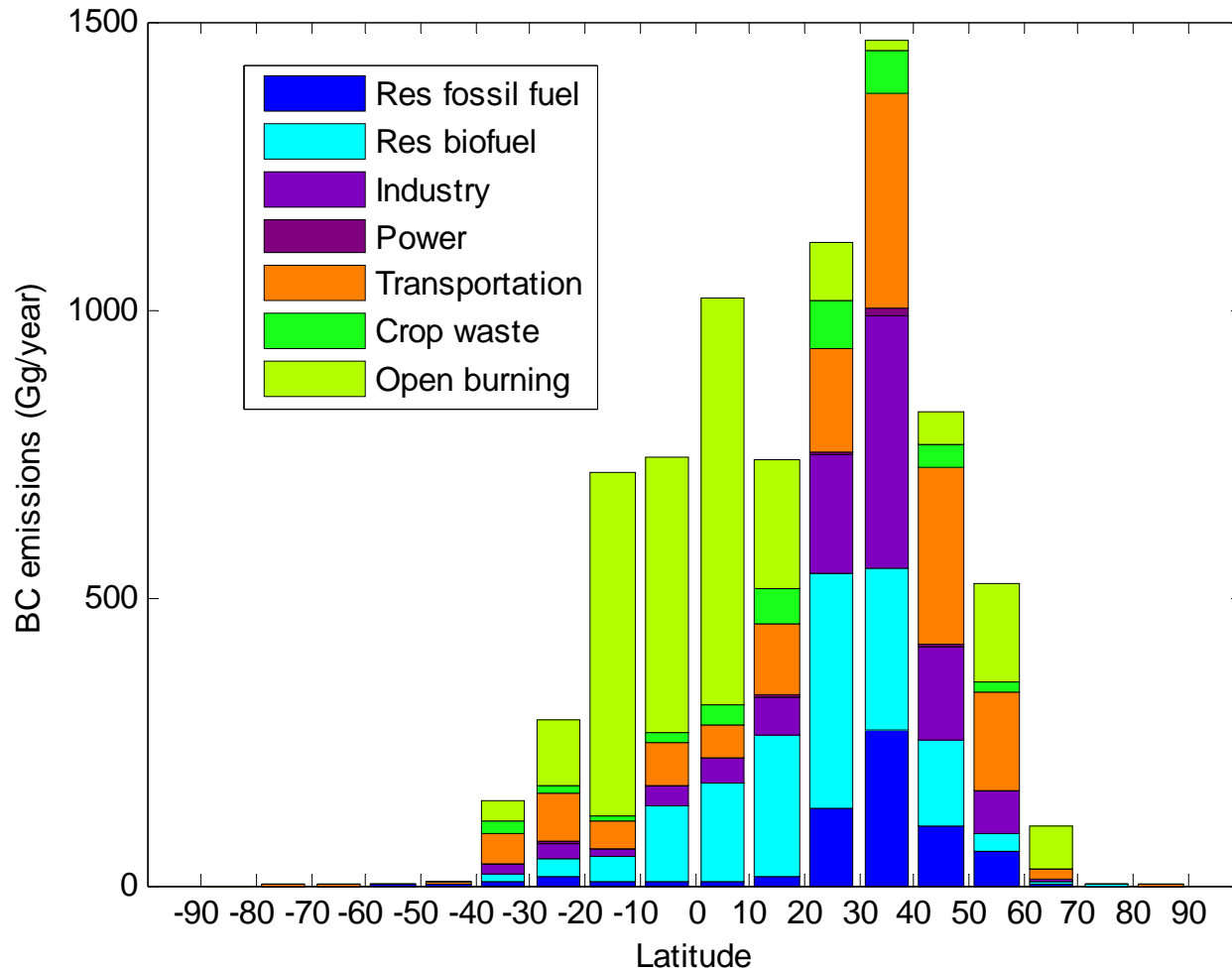
Total ~8000 Gg/year



Source: Bond et al., 2004



# Emissions of black carbon by source & location



Source: Bond et al., 2004 (updated to year 2000 data)  
GFEDv2 (van der Werf, 2006)



# Mitigation potential

## *Atmospheric mitigation*

- ❑ **Goal:** Reduce atmospheric warming
- ❑ Is reduced by co-emitted species  
*(organic carbon, sulfur)*
- ❑ Should consider cloud changes

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## *Arctic mitigation*

- ❑ **Goal:** Target warming & melting
- ❑ Not affected by co-emitted species
- ❑ Should consider cloud changes  
*(different ones!)*



# Atmospheric mitigation: Diesel engines

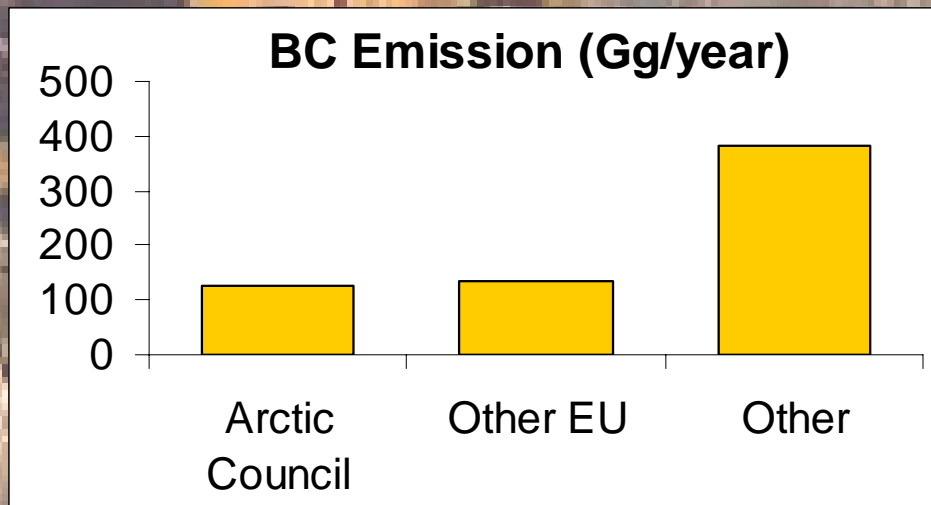
On-road, mobile off-road, stationary

- ✦ Mostly black carbon
  - reflecting organic carbon = small
- ✦ Organic carbon insoluble
  - cloud changes = small

*Atmosphere-Direct*  
**STRONG**



Image: [www.nada.org](http://www.nada.org)





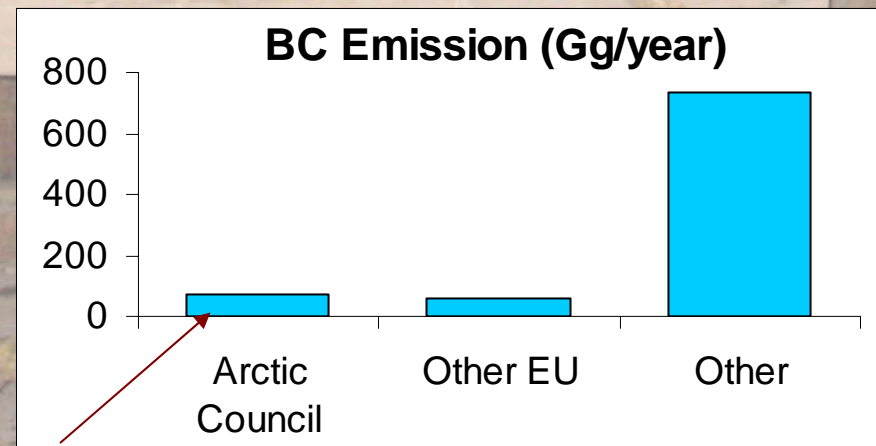
# Atmospheric mitigation: Wood/cooking

- ✦ Some organic carbon
  - may counteract black carbon, BUT
  - absorbs some light ~ net zero
  - mostly insoluble; cloud changes small
- ✦ Probably underestimated
  - in-use emissions higher than lab
- ✦ VOC + CO emission

*Atmosphere-Direct*  
**MODERATE**

TO

**STRONG**



*probably not cooking*

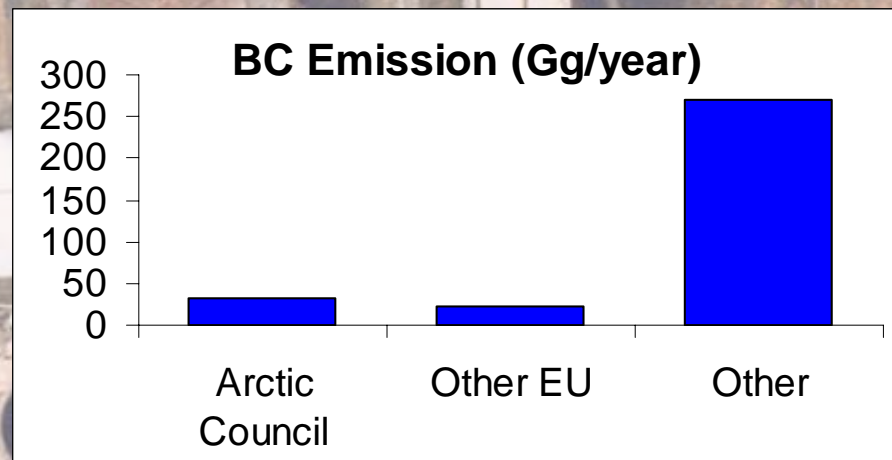


# Atmospheric mitigation: Domestic coal

- ✦ Some organic carbon
  - absorbs some light; may be net zero
- ✦ Sulfur emissions
  - direct forcing
  - may increase indirect effect

✦ Work needed:  
*Simulations of net carbonaceous + sulfur forcing*

*Atmosphere-Direct*  
**OPEN QUESTIONS**





# Atmospheric mitigation: Industry

- ✦ Chemical composition uncertain
- ✦ Emission magnitude uncertain

*Atmosphere-Direct*  
**OPEN  
QUESTIONS**

- ✦ Research needed:

*Emission measurements!* *Small industry+boilers, developing countries & countries in transition*

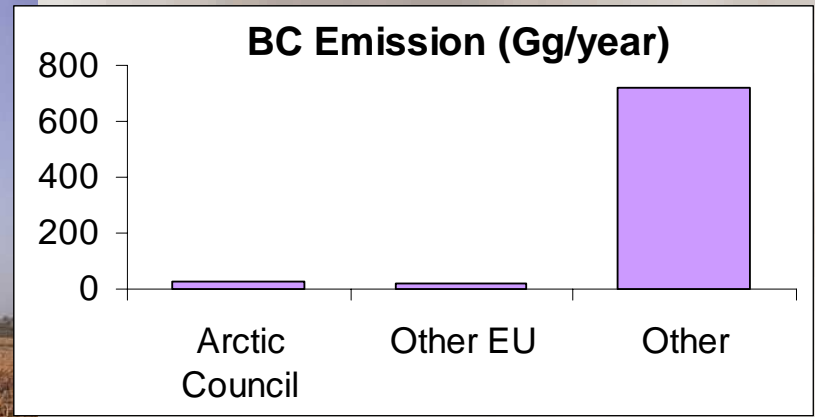
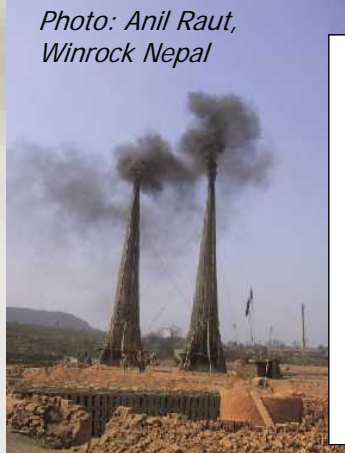


Photo: The News Pakistan, 05 Nov 2007

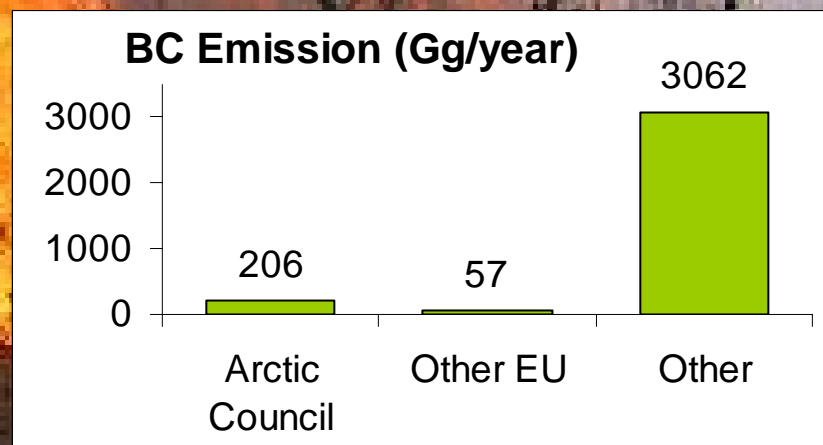


# Atmospheric mitigation: Open biomass

- ★ Emitted organic carbon
  - counteracts black carbon
- ★ Soluble organic carbon
  - alters cloud formation → brighter clouds
- ★ Very large source of CO, VOCs
- ★ Increased land albedo

- ★ Research needed:  
*Identify specific burning types with positive atmospheric forcing??*

Atmosphere-Direct  
**OPEN  
QUESTIONS**



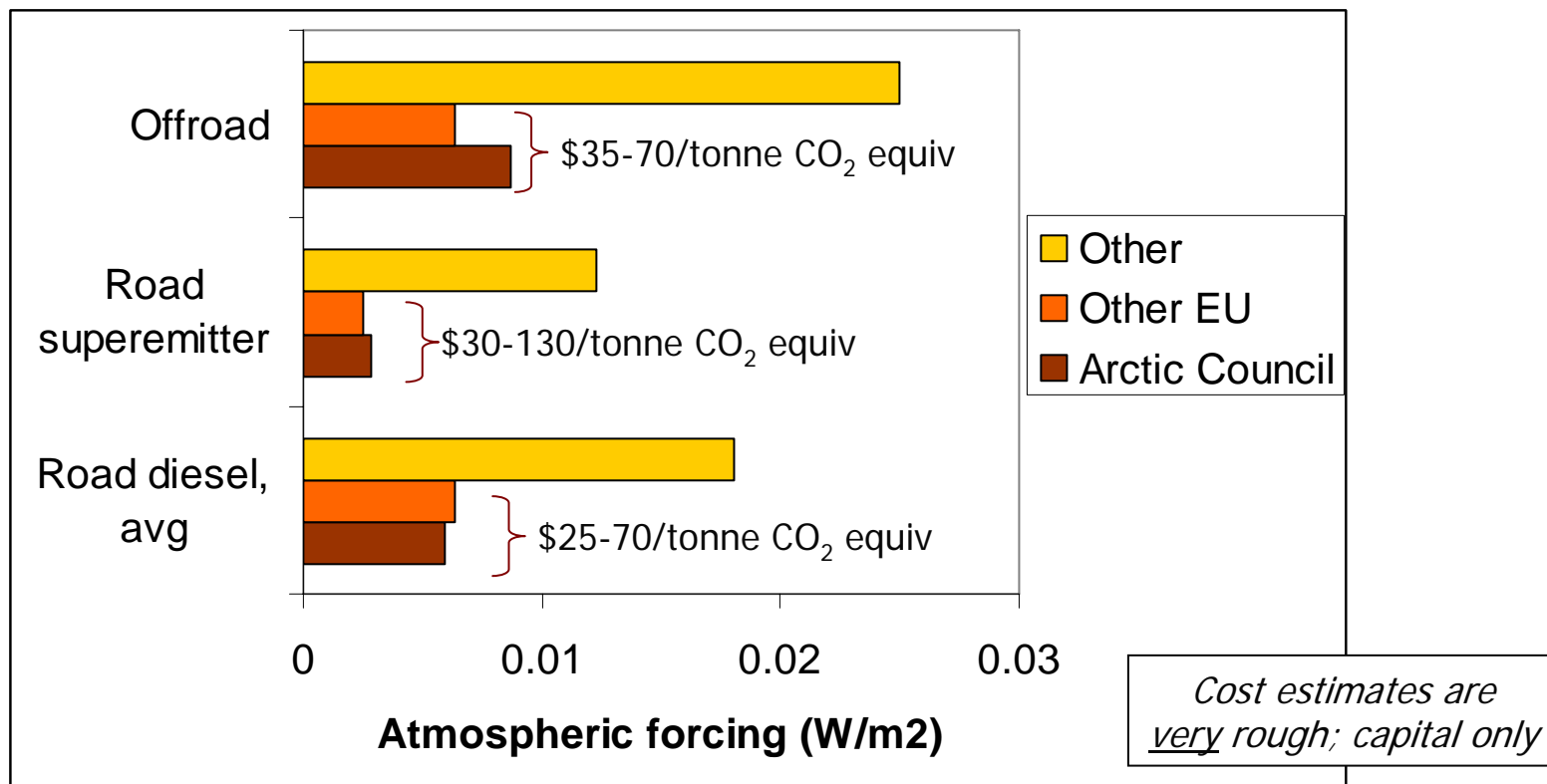


# Mitigation potential

	Known Arctic deposition	Reduce atmospheric warming	Mitigation feasibility	
Diesel engines	POTENTIAL	STRONG	EXISTS	POSSIBLE
Wood for cooking		STRONG-MOD	EXISTS	POSSIBLE
Domestic coal		OPEN QNS	EXISTS	POSSIBLE
Industry	POTENTIAL	OPEN QNS	EXISTS	POSSIBLE
Open biomass	POTENTIAL	OPEN QNS	QUESTIONABLE	



# Diesel engines



## Advantages

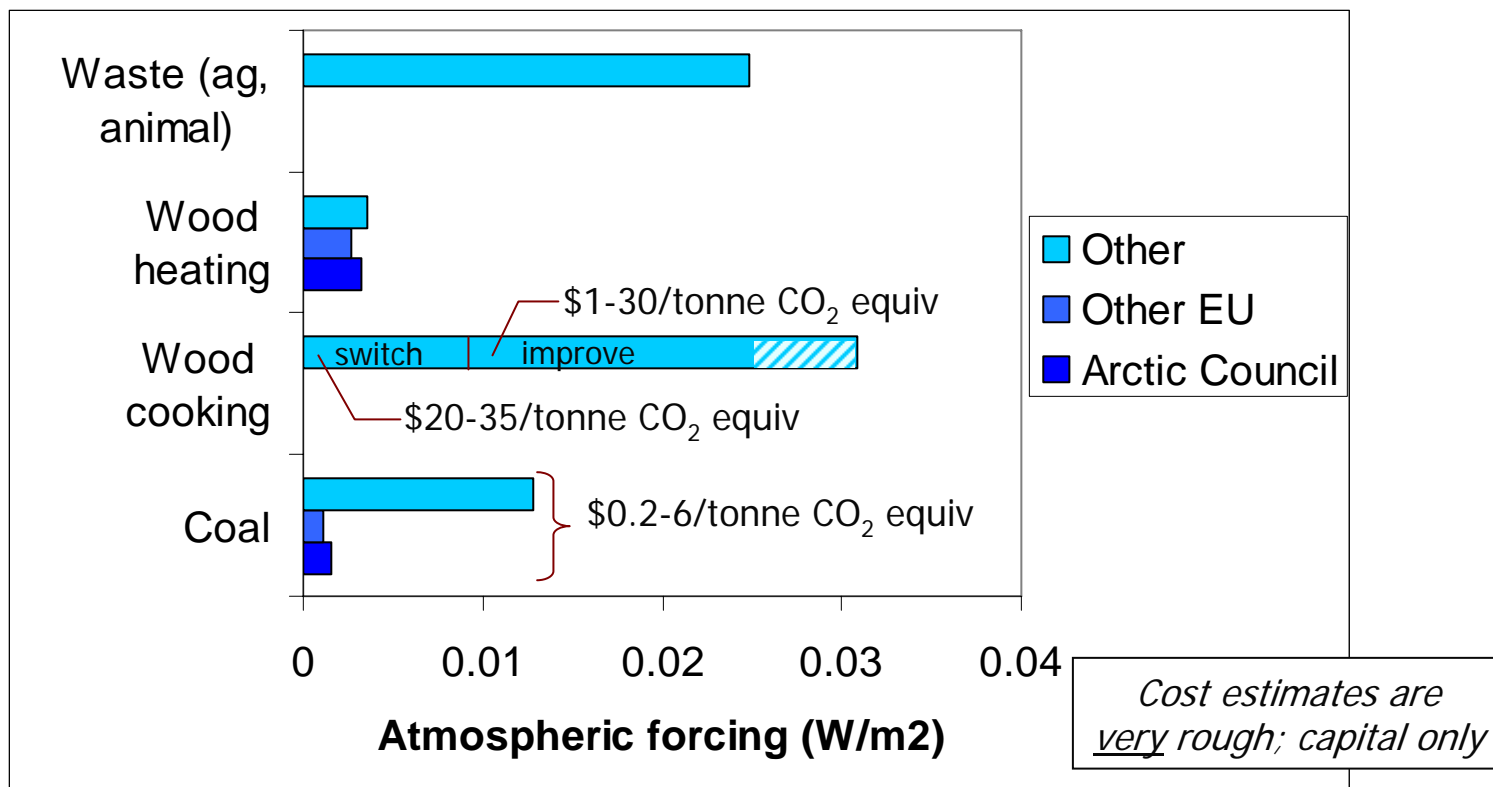
- ★ Most convincing warmer
- ★ Existing, proven reduction mechanisms

## Challenges

- ★ Need low-sulfur fuel
- ★ Implement regulations *before* growth
- ★ Longevity of fleet, especially *off-road*
- ★ Locating & targeting *superemitters*



# Residential solid fuel



## Advantages

- ★ Rapid turnover
- ★ Important health benefits (indoor air)
- ★ Address MDGs

## Challenges

- ★ Distribution networks
- ★ Cost of *BC-reducing* stoves (gasifier-type?)
- ★ Capital (& operating) cost
- ★ Permanence



# Summary

Feasibility

**EXISTS** **POSSIBLE**

