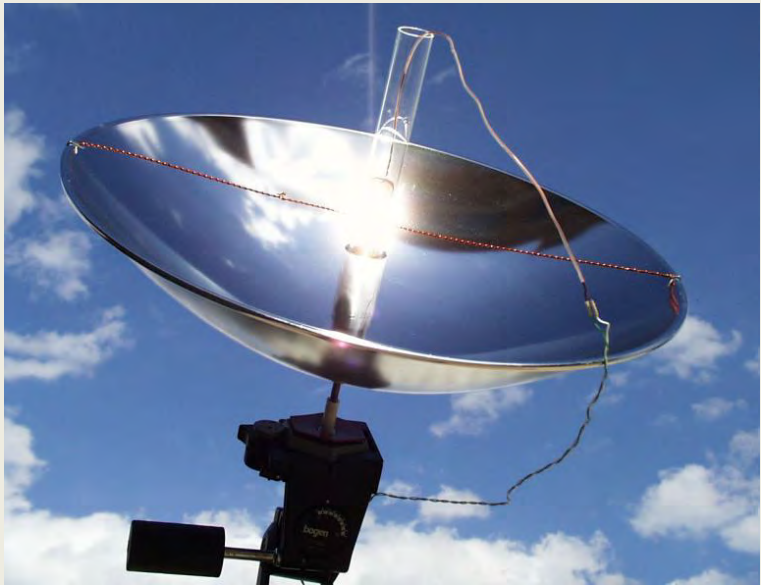
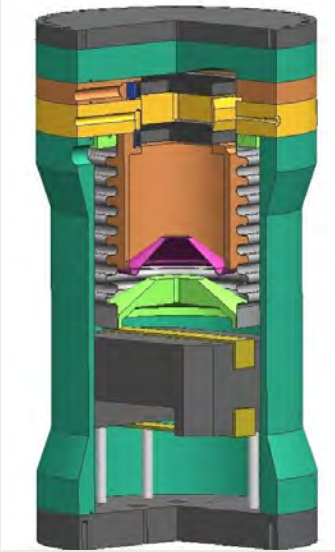
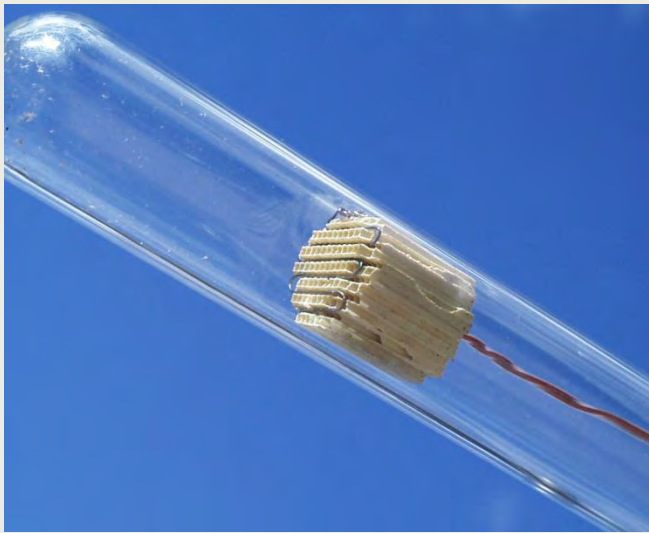




Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE NOV 2009		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Utilizing Stove Heat for Co-Generation				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US State Department -Jefferson Science Fellow Penn State -United Technologies Corporation Professor of Acoustics				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM002337. US-ASEAN Next-Generation Cook Stove Workshop Held in Bangkok, Thailand on November 16-20, 2009. U.S. Government or Federal Purpose Rights License, The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 19	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



Bureau of East Asian and Pacific Affairs



ASEAN-US Next-Generation Cook Stove Workshop:
Session 4 – Utilizing Stove Heat for Co-Generation
Wednesday Afternoon - 18 Dec 2009

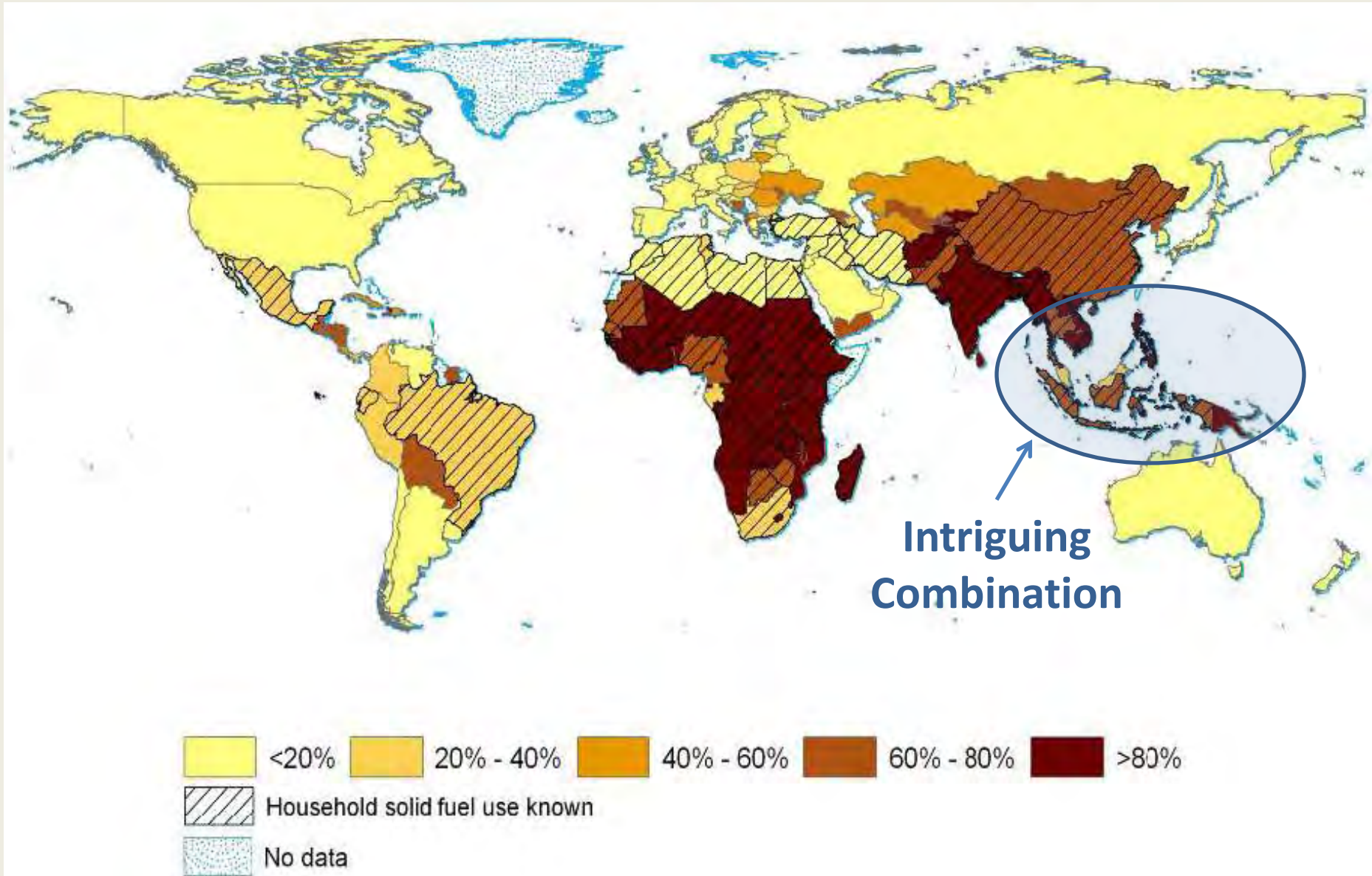
Session Introduction

Steven Garrett

US State Department - Jefferson Science Fellow

Penn State - United Technologies Corporation Professor of Acoustics

National Household Solid Fuel Use in 2000



The Photons of Modernity



Technology is IMPORTANT

“If user demand were the sole driver of innovation, the biomass cooking stove would be one of the most sophisticated devices in the world.”

The Economist, 6 Dec 2008



Philips Woodstove
for India

Field Test of 50 Units
in India

“Wall Wart” Charger

- **Fans improve performance**
 - Fuel flexibility (e.g., rice husks)
 - Reduced cooking time
 - Power control (boil vs. simmer)
 - Much lower toxic pollutants
 - Much lower soot production
- **Fans require electricity**
 - Available in India and China
 - Scarce elsewhere



Rice Husks in
the Philippines

Alex Belonio
Winner of 2008
Rolex Award

Chinese Hybrid Gasifier Stove

National Stove Contest Winner 2008

Efficiency 2x traditional stoves; Emissions 10-15x less:
Low health risk and essentially no greenhouse emissions



Compared to Coal Stove

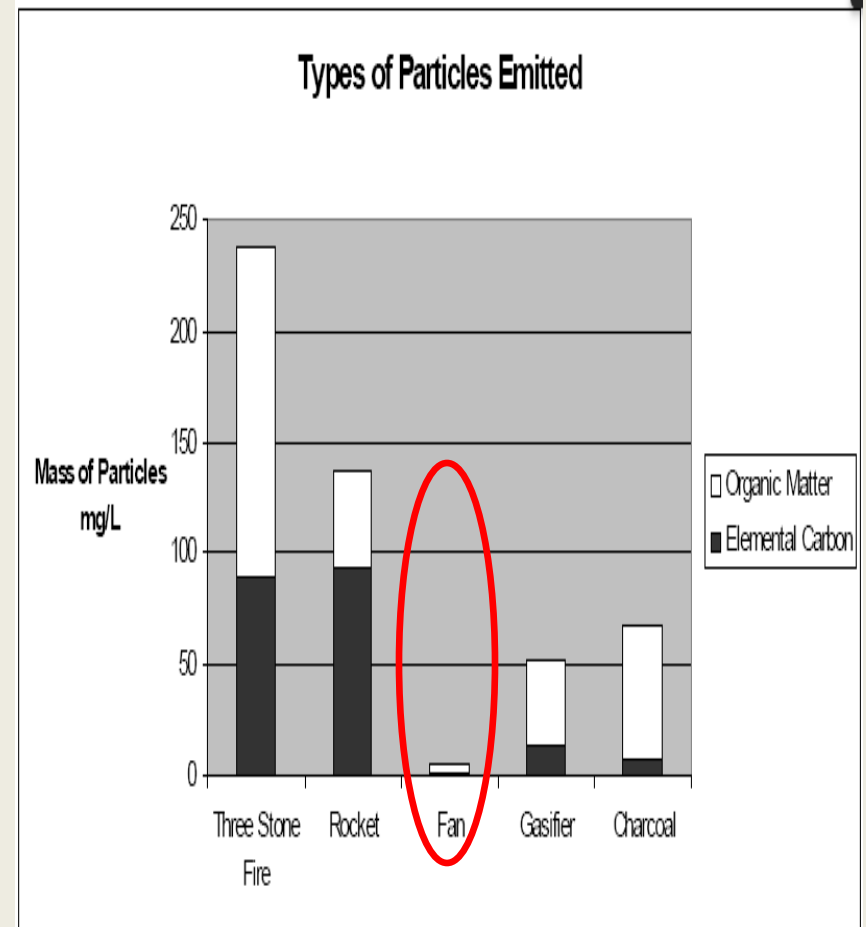
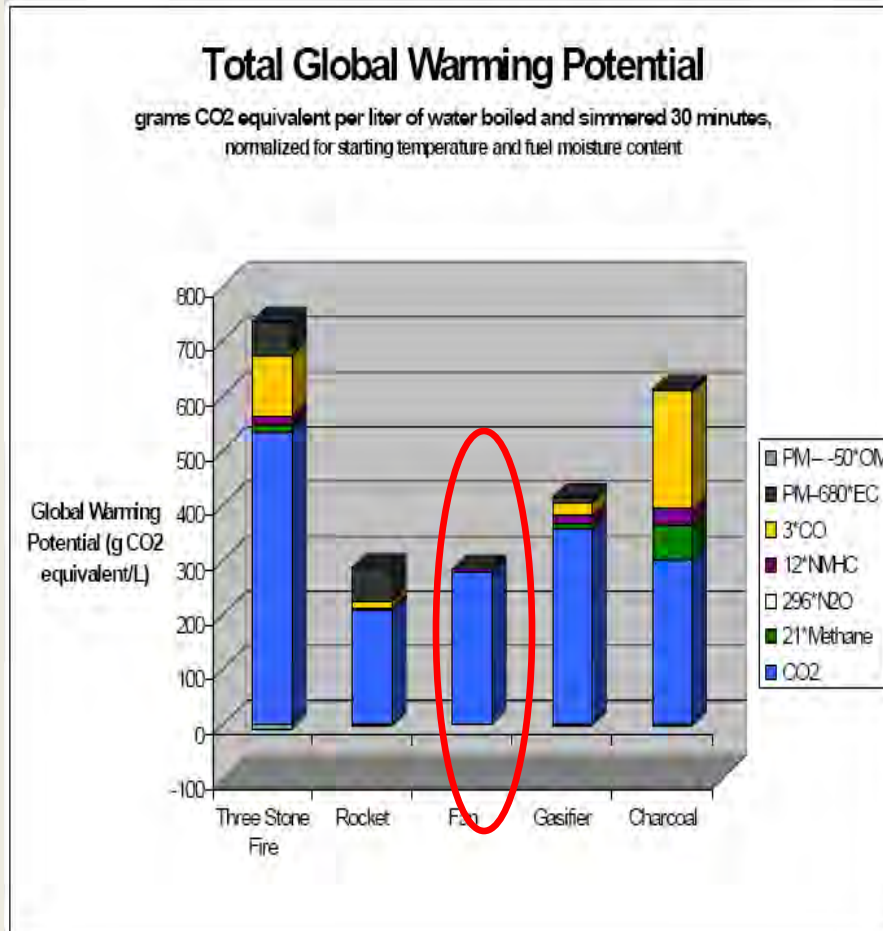
17% to 41% fuel efficiency

0.12 to 0.02 CO/CO₂

1.6 to 0.26 g PM/kg fuel

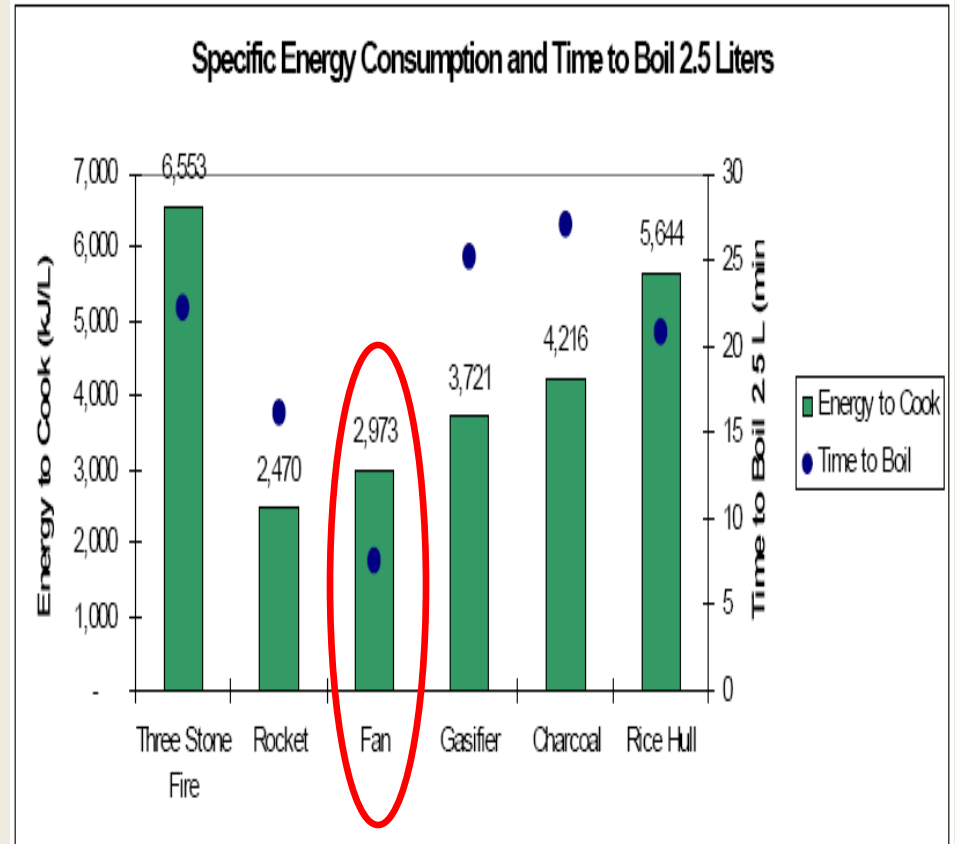
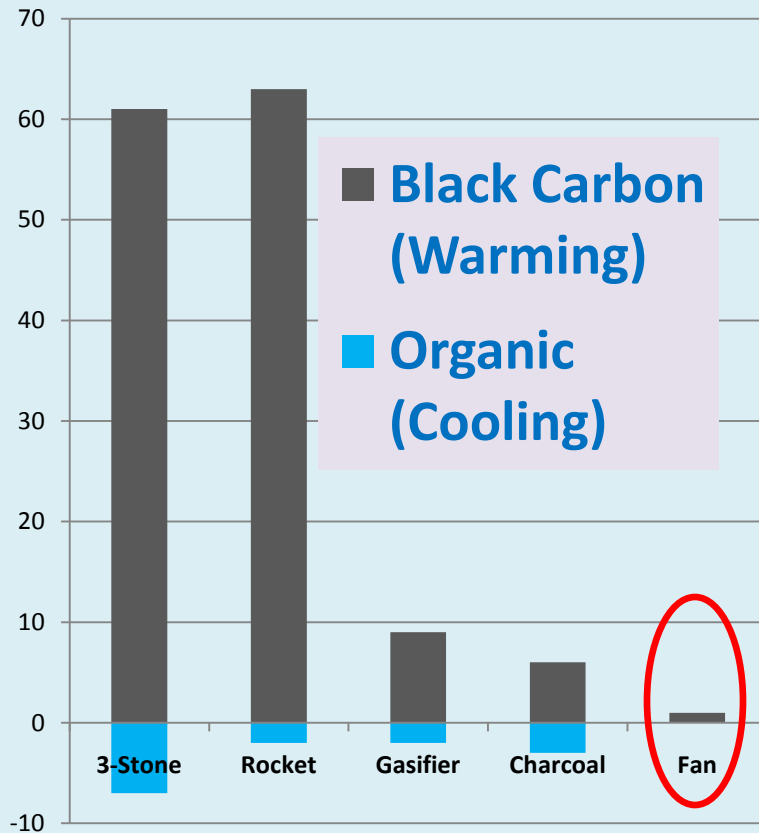
18 W blower

Fans Help: GWP and Particles



N. MacCarty, D. Ogle, D. Still, T. Bond, C. Roden and B. Willson, *Laboratory Comparison of the Global-Warming Potential of Six Categories of Biomass Cooking Stoves*, Tech. Report, 26-pages, Aprovecho Research Center, Advanced Studies in Appropriate Technology, Creswell, OR (Sept. 2007).

Black Carbon (Soot) and Cooking Time

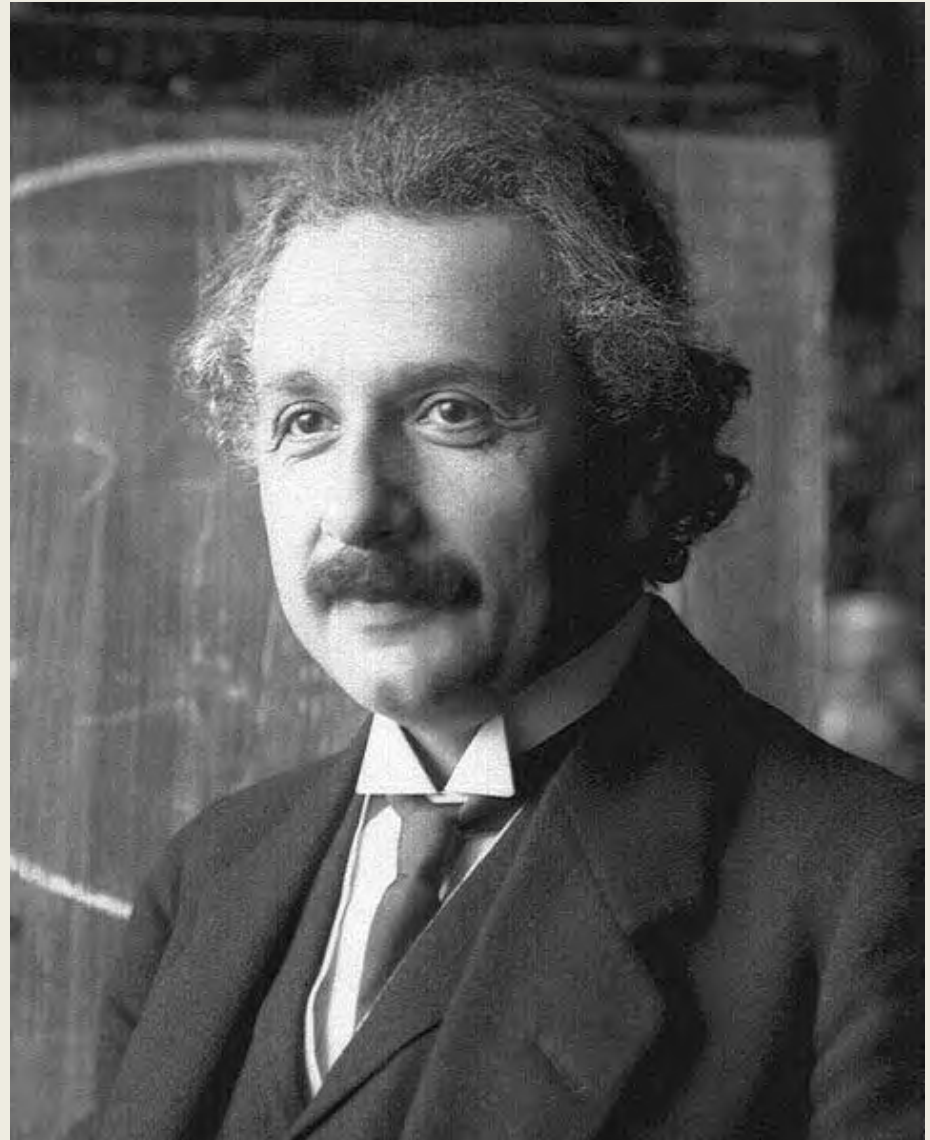


Nobody wants to spend more time doing food preparation!

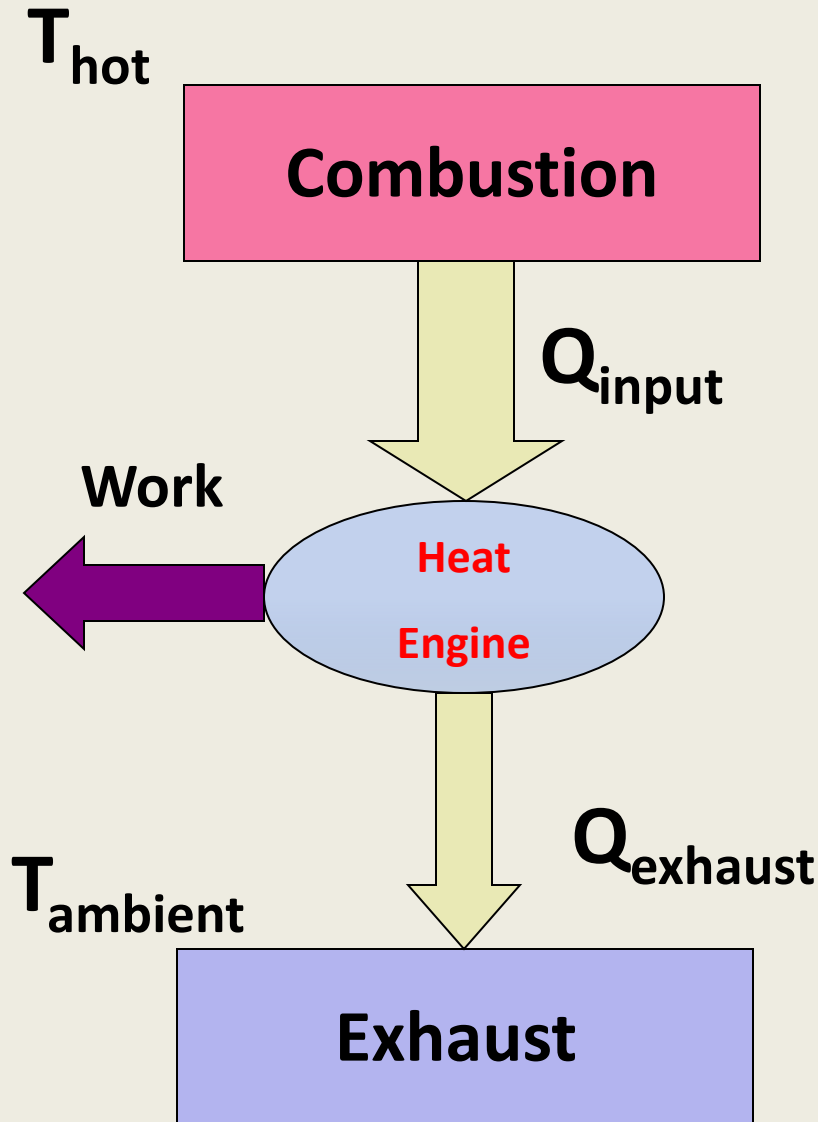
Thermodynamics

“It is the only physical theory of universal content that, within the framework of applicability of its basic concepts, ***will never be overthrown.***”

Albert Einstein,
"Autobiographical Notes", 1949



Heat Is Not All Created Equal



- **The 1st Law**

- Energy is conserved

$$Q_{exhaust} + \text{Work} = Q_{input}$$

- **The 2nd Law**

- Entropy increases

$$\Delta S = \Delta Q/T$$

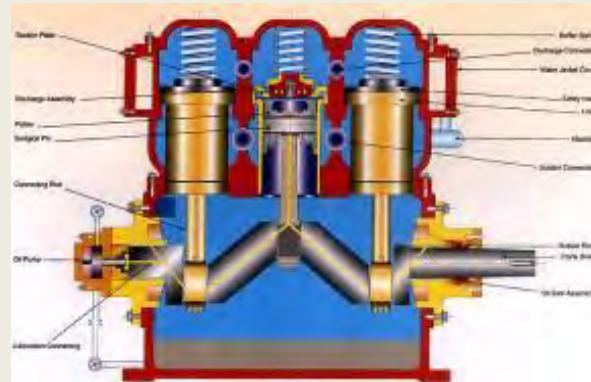
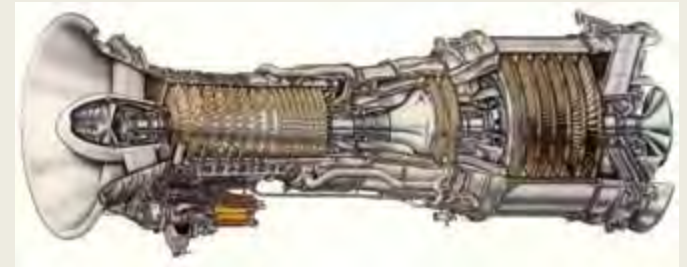
$$\text{Efficiency} = \frac{\text{Work}}{Q_{input}} \leq \frac{T_{hot} - T_{ambient}}{T_{hot}}$$



Session 4 – Utilizing Stove Heat for Co-Generation

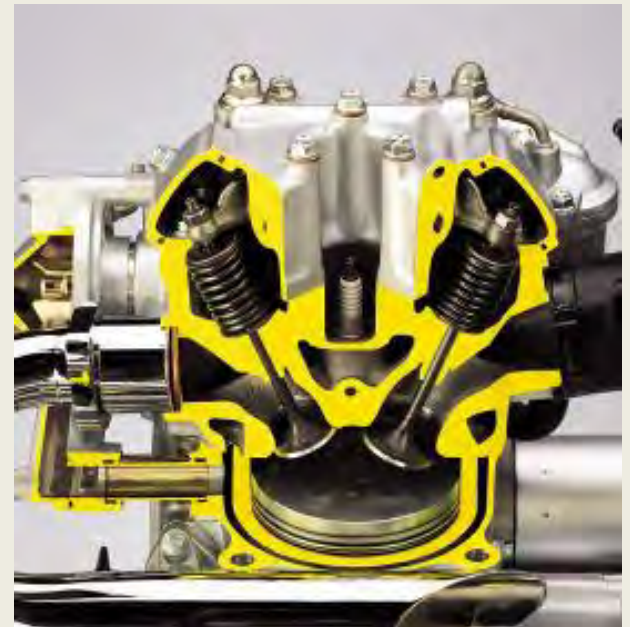
- | | |
|-------------|---|
| 1:10 – 1:30 | Thermoelectric stove (B. Willson) |
| 1:35 – 1:55 | Thermoelectric stove (C. Lertsatitthanakorn) |
| 2:00 – 2:20 | Thermoelectric fan stove (J. Ceder) |
| 2:25 – 2:40 | Break |
| 2:40 – 3:10 | Thermoacoustic cogeneration applied to advanced cook stoves (S. Backhaus) |
| 3:15 – 3:35 | SCORE Project thermoacoustic co-generator (C. Lawn) |
| 3:40 – 4:00 | Steam electrical co-generation (C. do Canto Muniz) |
| 4:05 – 5:45 | Break-Out Sessions on Research Needs for Co-Generation |
| 5:45 – 6:00 | Co-Generation Break-Out Group Reports (B108) |
| 6:10 – 7:45 | Dinner |
| 7:45 – 7:50 | Presentation of Tomorrow's Schedule |

Familiar Heat Engines

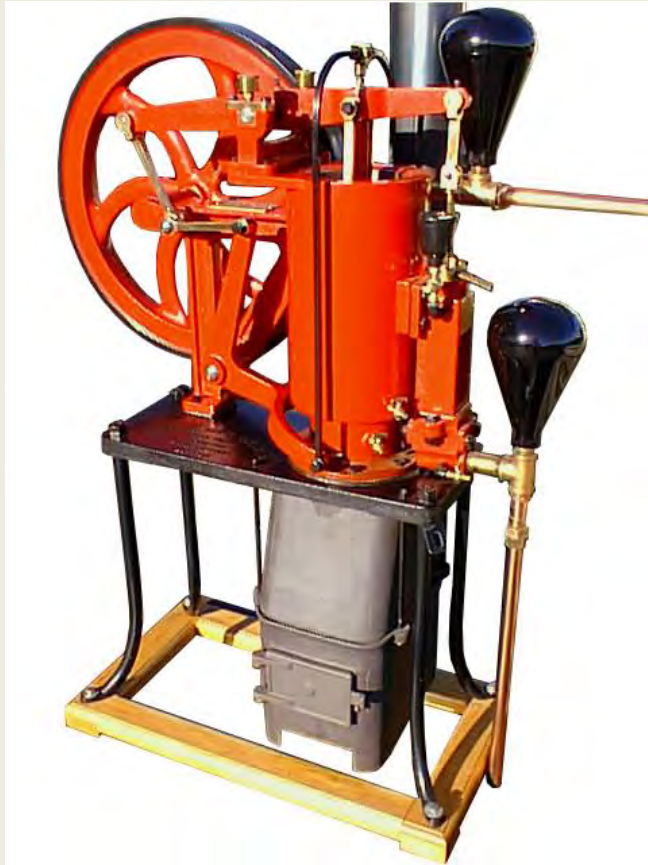


Pistons, Pushrods, Cams, Valves

It's all
about
phasing!



Closed-Cycle Engine Technology



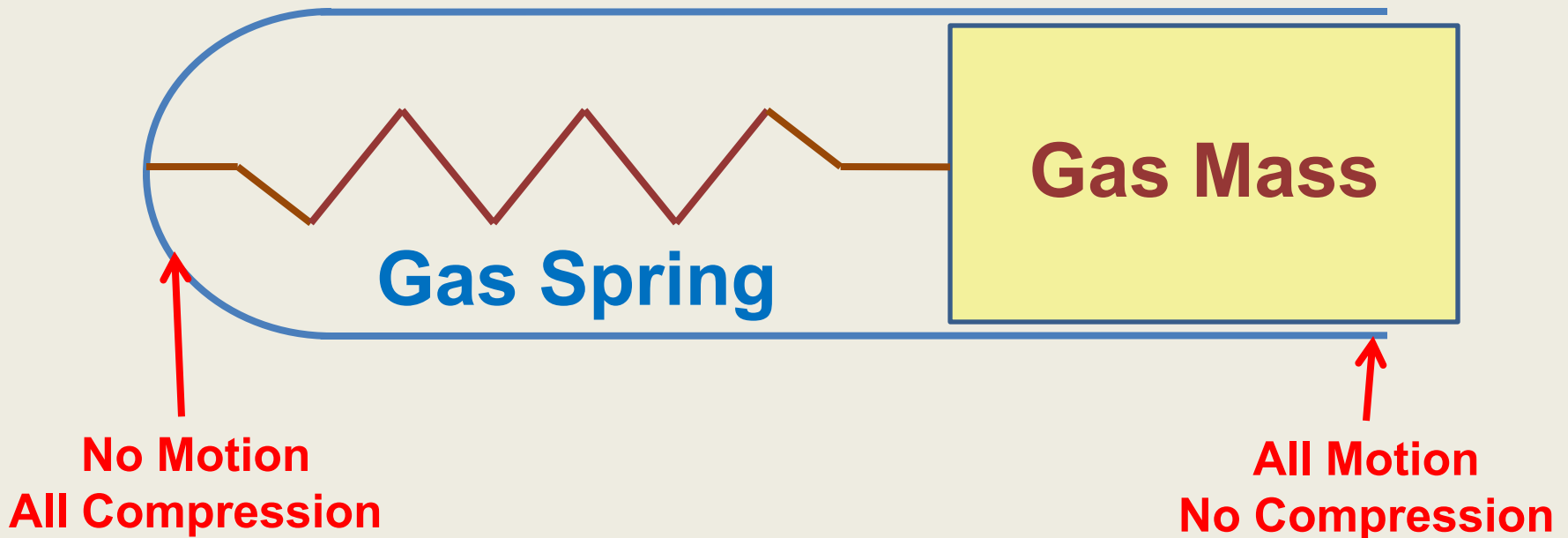
1895 Rider-Ericsson



2001 WhisperGen

Resonant Acoustical Phasing

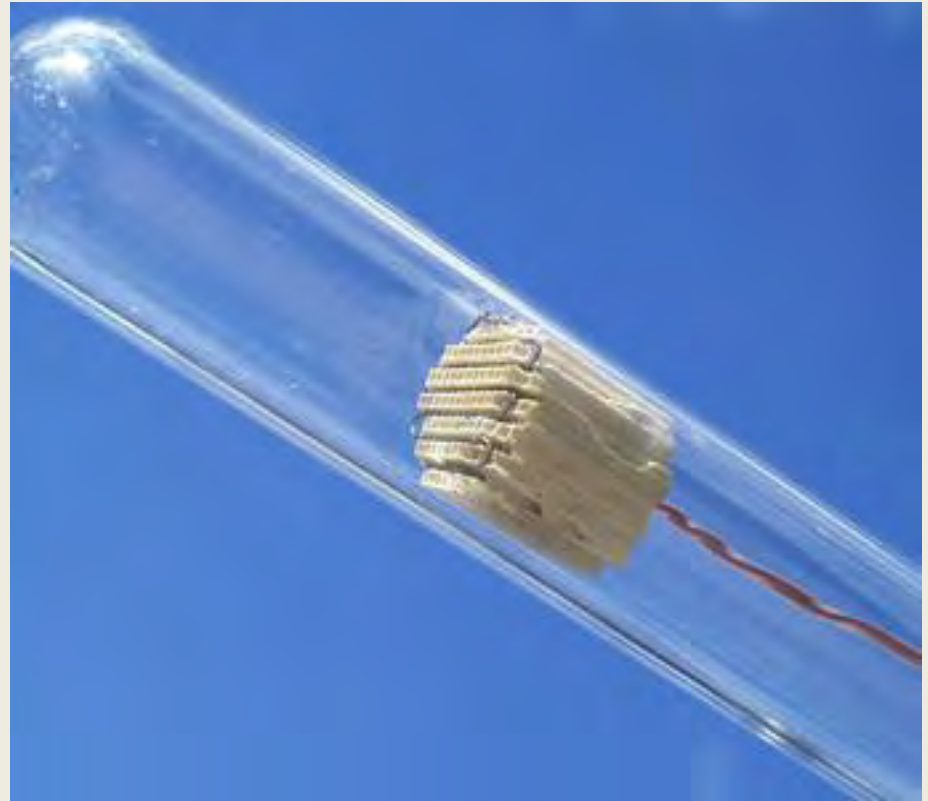
[For a natural engine]



Gas Compliance $\leftrightarrow$ Gas Inertance $\Rightarrow$ Harmonic Oscillations

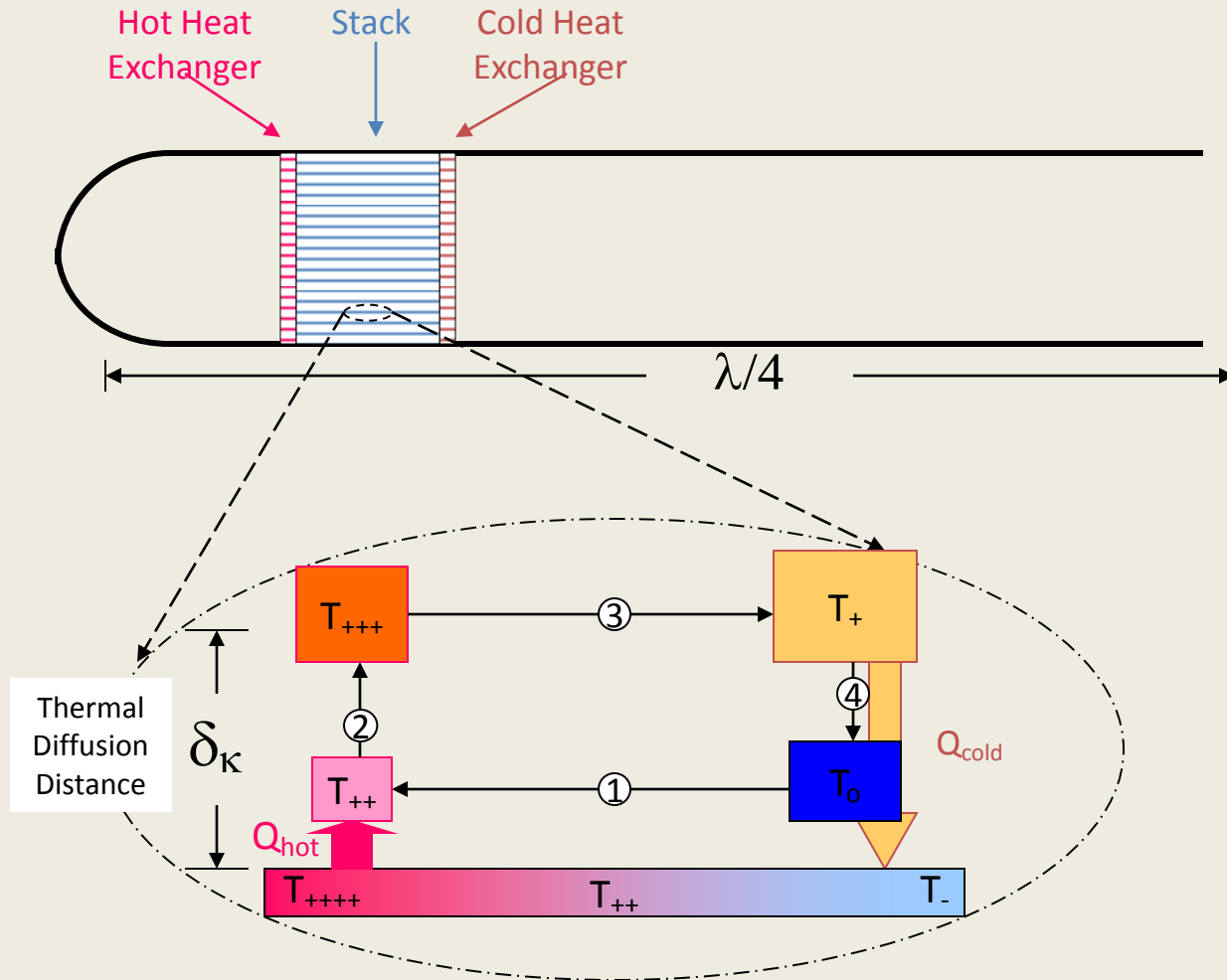
Thermoacoustic Engine Demonstration

- Heat and Heat Engines
 - Cook stoves are **hot**
 - Heat can produce **work**
- Convert **work** to **electricity**
 - Generators
 - Linear alternators
- External combustion
 - Free piston Stirling
 - Steam (piston or turbine)
 - Thermoelectric
 - Thermoacoustic



- Engine Requirements
 - **Robust**
 - **Inexpensive**
 - **Low maintenance**

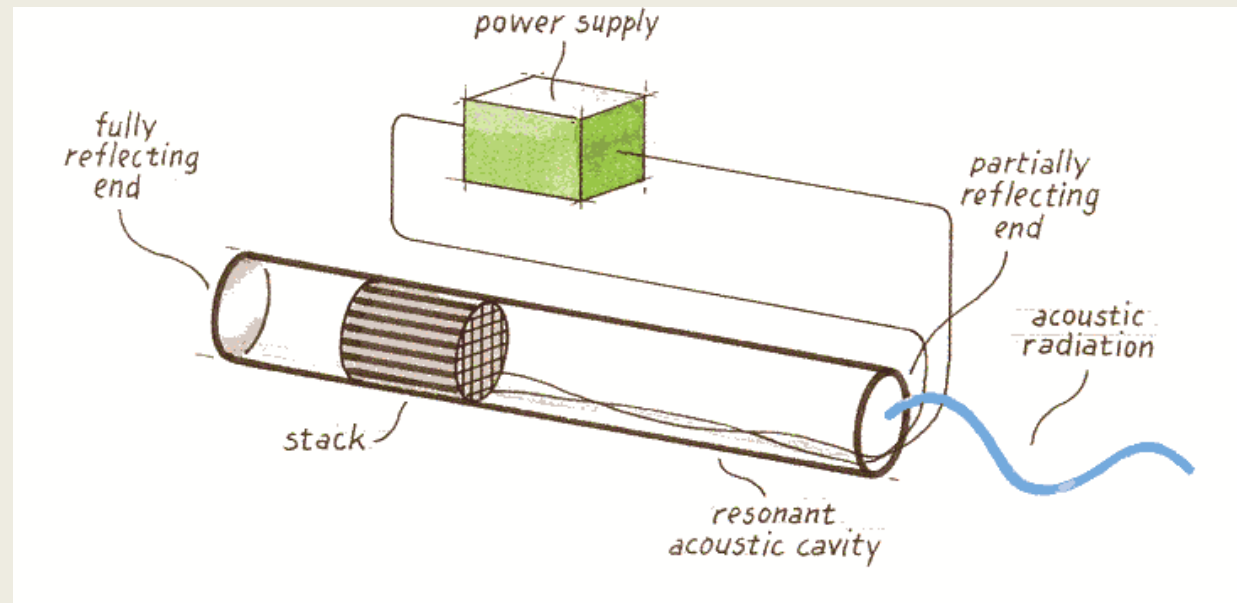
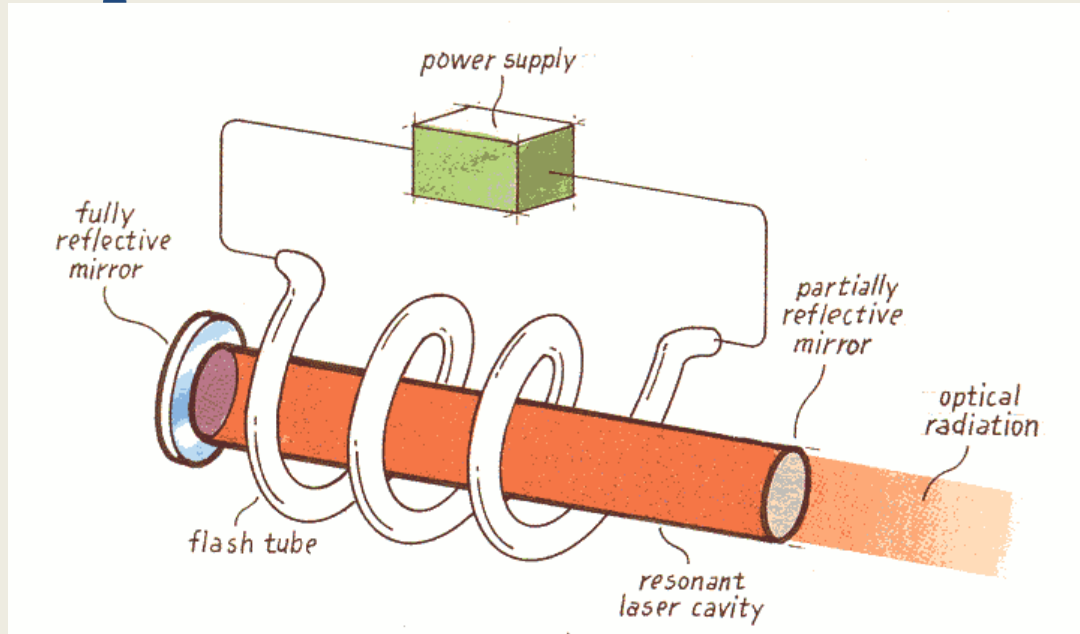
Standing-Wave Prime Mover - Lagrangian Model



Optical Laser

-

Acoustical Laser



Next-Generation Cook Stove Workshop

Asian Institute of Technology: 16-20 Nov 2009

- How do you run a fan **without a power grid**?
 - Small scale heat engine technologists.
- How do you stimulate **adoption** of new stoves?
 - Corollary benefits of rural electrification.
- How do you make **millions of them**?
 - Indigenous manufacturing technologists.
- How do you **purchase** all those stoves?
 - Micro-finance and carbon credits experts.
- How do you **distribute** all those stoves?
 - Local merchants and entrepreneurs.
- Outputs?
 - **Design teams** for engines and monitoring.
 - Test, monitoring and **evaluation team**.