

# Status of Biomass Gasifier Village Systems

Ralph P. Overend  
National Renewable Energy Laboratory

For: Village Power '98  
World Bank Headquarters  
Washington, DC. October 6 - 8, 1998

# Biomass and Village Energy

Biomass is the World's 4th Energy Source

Usage of Biomass is widespread in both Industrial and Developing Countries

The majority is used to provide heat

Worldwide 15 PWh thermal and about 150 TWh electricity (15% and 1% of world totals)

Is renewable if the resource base is managed sustainably

Advantage in being despatchable

# Biomass Utilization

Pervasive in Rural, Urban and Industrial Settings

## Daily living

- Cookstoves
- Space heating

## Community Applications

- District Heating, Institutions (Hospitals, Administrative Centres)
- Village Industries
  - Drying Kilns, Ovens, Lime Kilns

## Industries

- Wood Processing
- Sugar Mills
- Palm Oil

# Power and Electricity from Biomass

Mainly in Industry Today - Using “captive” Residues

## Commercially Available

- Large Scale > 1 MWE output
  - Steam Boiler and Turbines
- Small Scale < 1 MWE output
  - Steam Boiler and Turbines
  - Gasifiers and Internal Combustion Engines

## Emerging Technologies

- Gasifier/Combustor - Stirling Cycle
- Gasifier/Combustor - Gas Turbine (Brayton Cycle)
  - Direct-fired
  - Indirect
- Gasifier - Fuel Cell

# Biomass to Power Systems

Sustainable Resources and Efficient Technologies are Needed

The essentials of a bioenergy system are:

Sustainable Resource Base

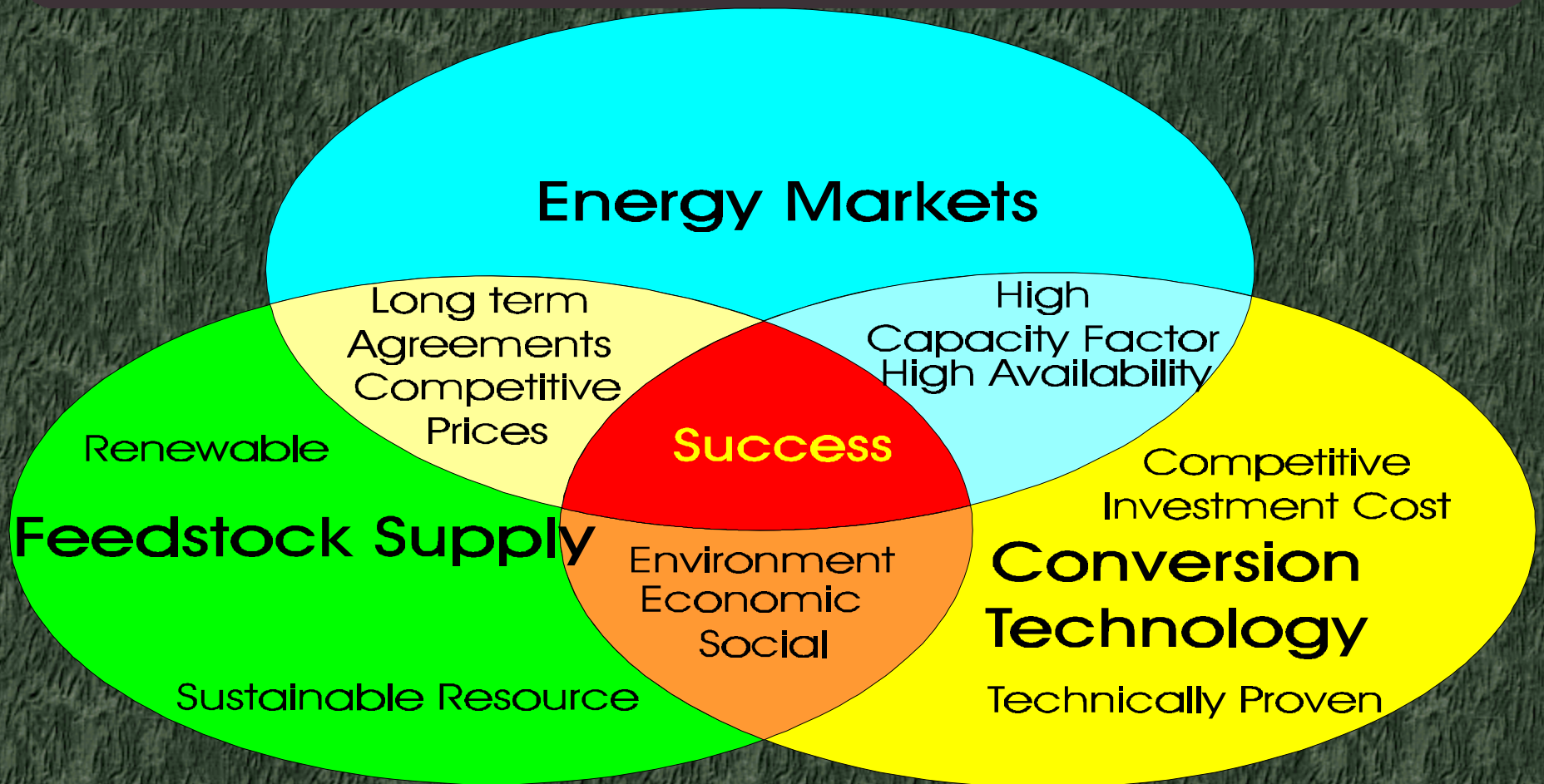
Reliable Technology

Environmental Quality

Revenue Generation to ensure Sustainability

# Biomass and Bioenergy

## Criteria for Success



# Resource Base Considerations

## Available Biomass Criteria

Available Land

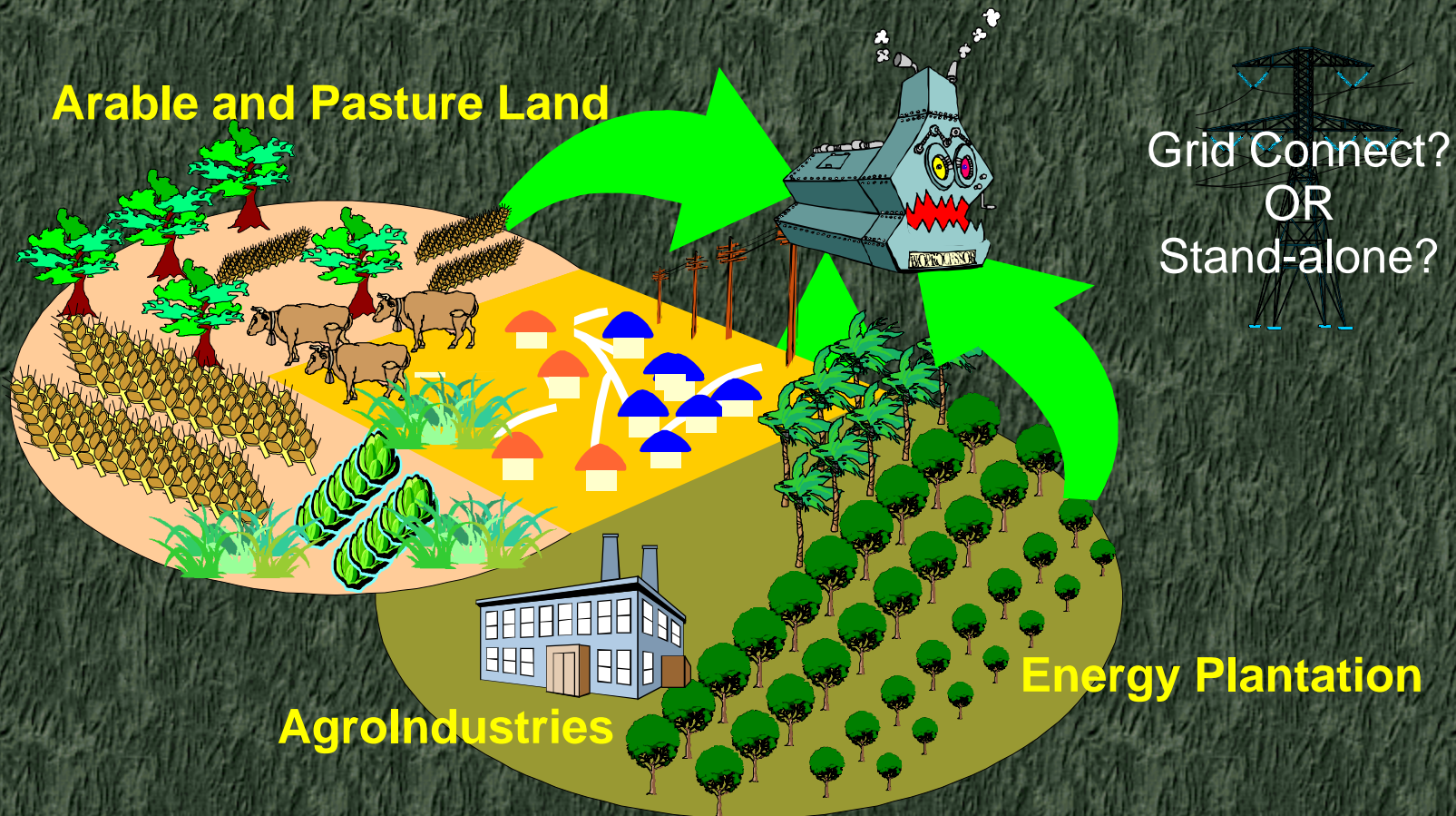
Crop Production Patterns

Competing Uses for the Resource

Logistics of gathering and storing prior to use

# Village Power from Biomass

## Potential Resources





# Conversion Efficiency and Land Productivity

Land Limited to Village Area

250 Households

4.8 kWh/day supply

(125 kW peak)

Land Available

500 ha Arable Land (India)

70 ha of Arable land (China)

**NO OTHER BIOMASS  
RESIDUE UTILIZATION**

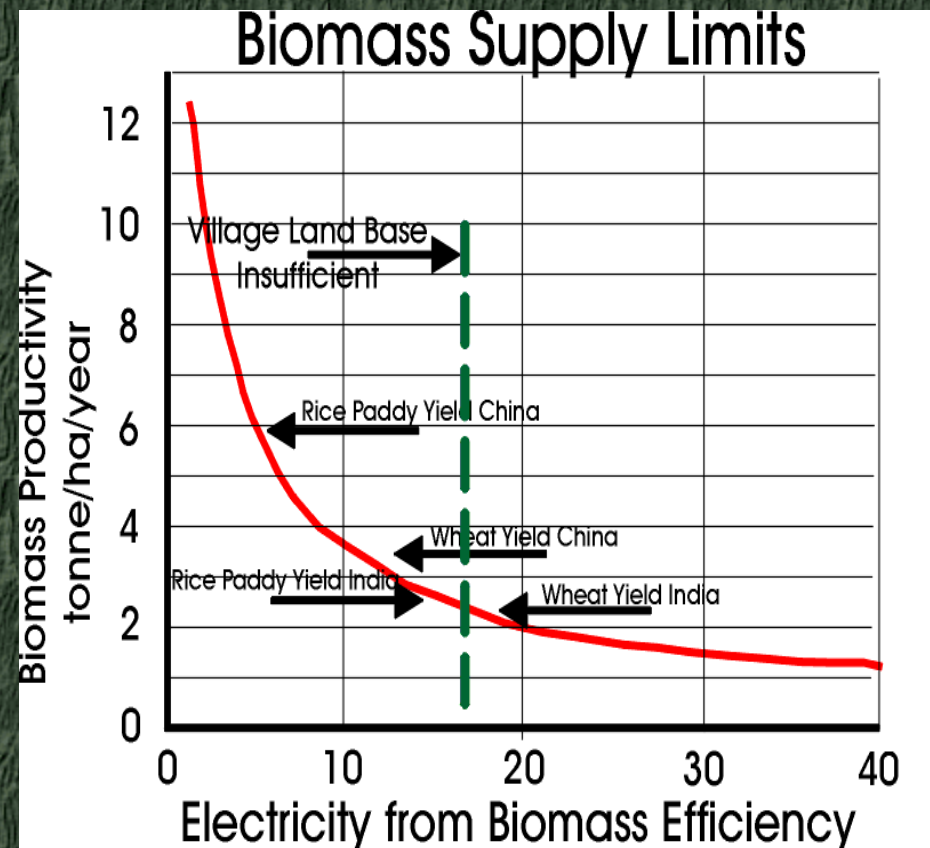
Daily Living

Animal Fodder

Animal Bedding

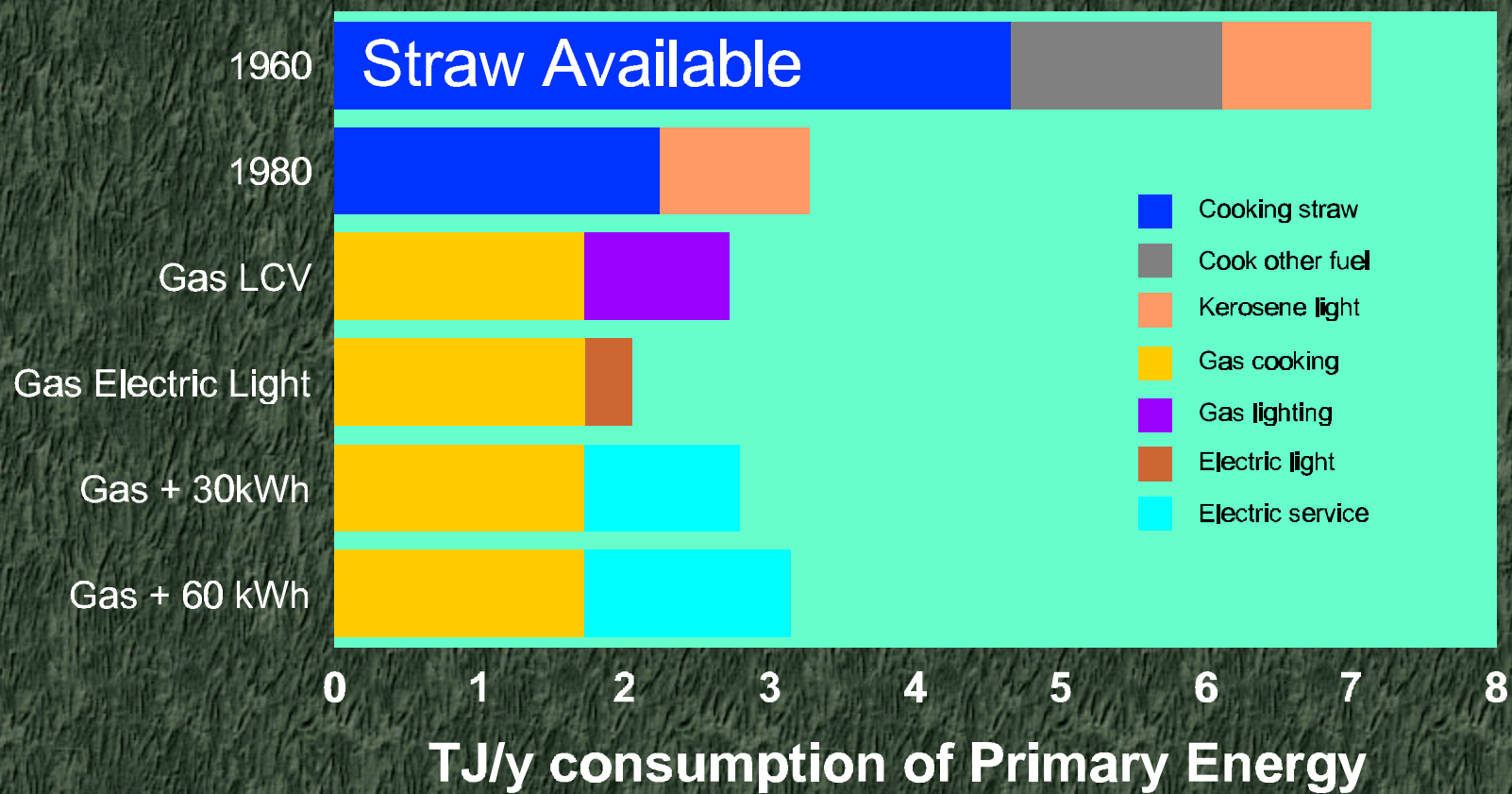
Fuel for Village Industry

Other products - paper



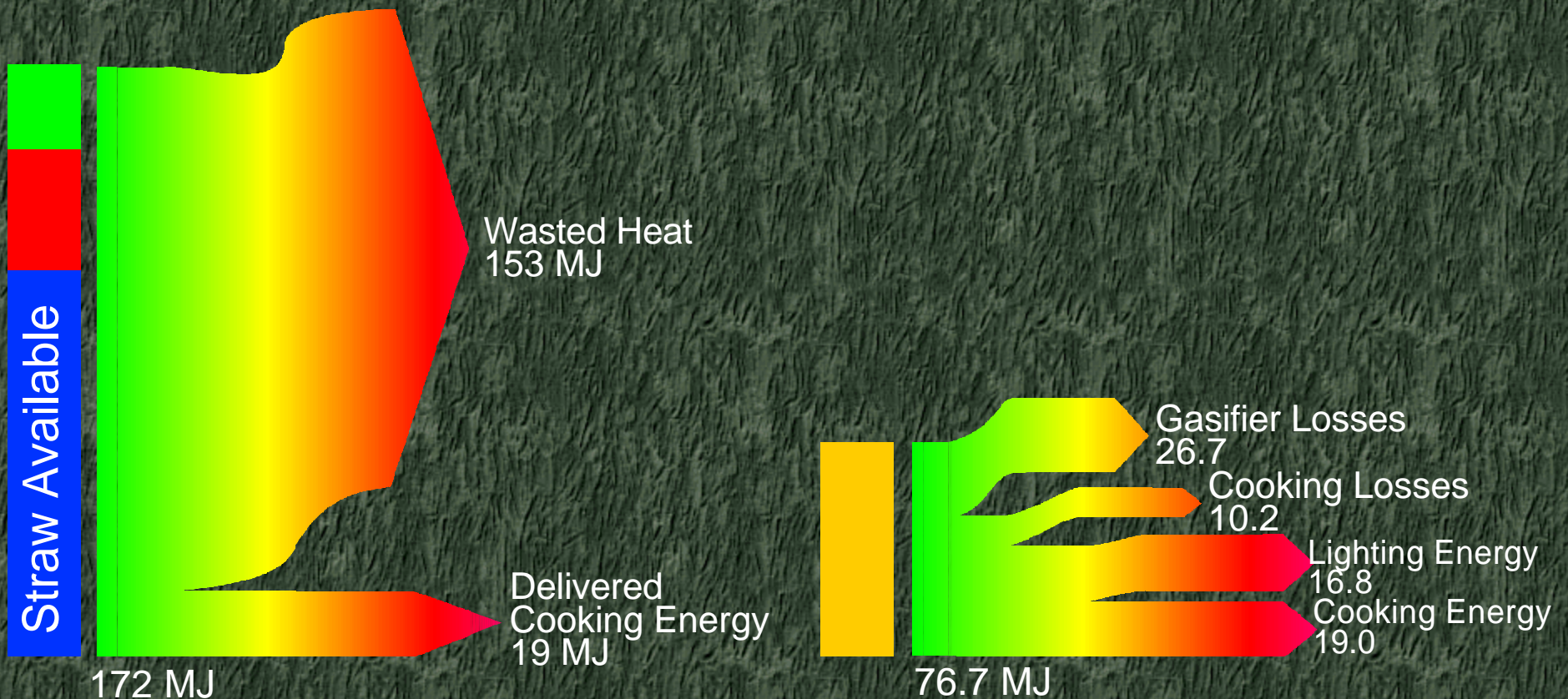
# Technology Makes for Better Service

100 households 20 hA arable land - double cropped



# Village Energy systems

Moving from 1960-2000



# Technology Options

## Biomass Pretreatment and Post Conversion

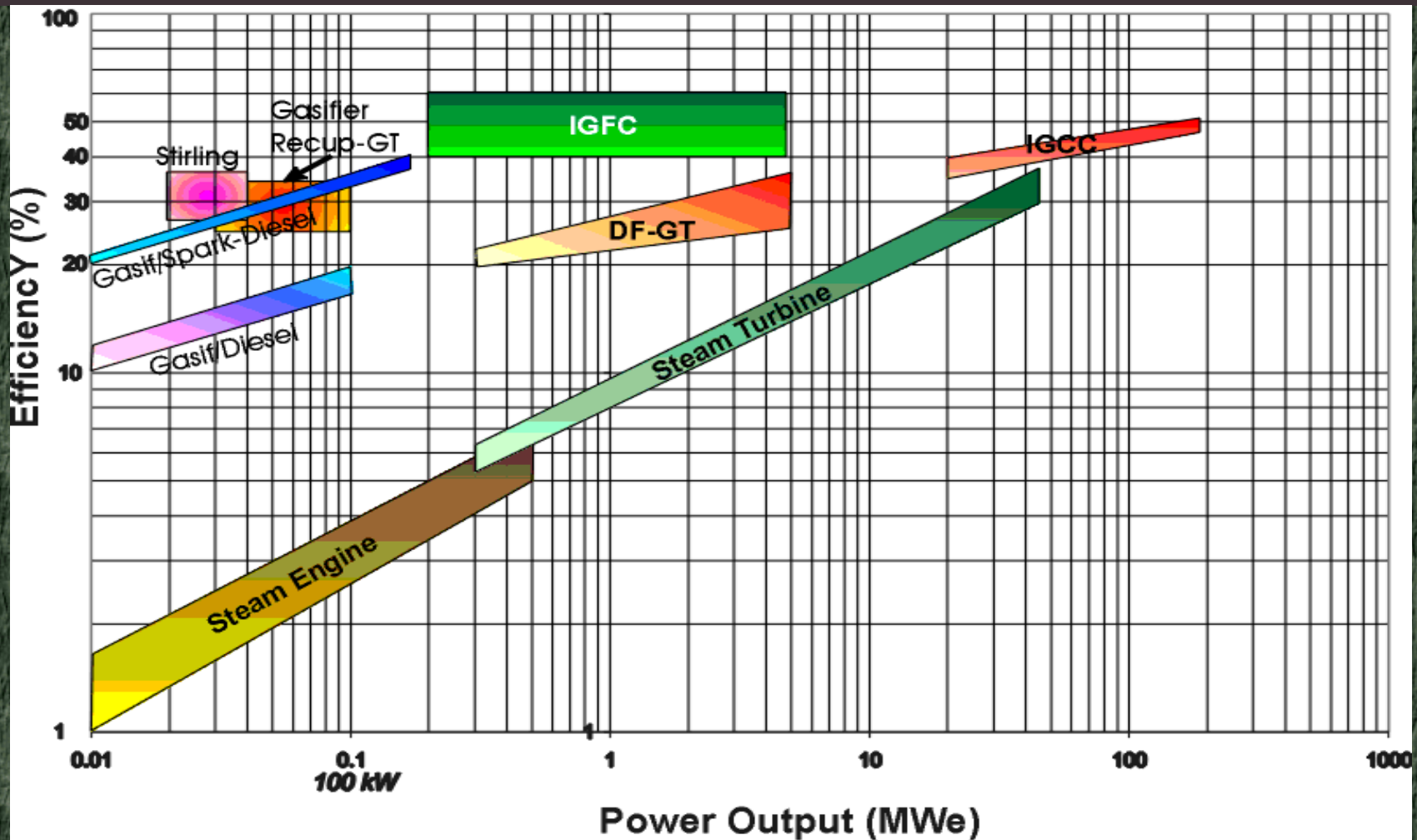
Physical (Size reduction, slurring, drying)

Combustion and Steam Generation

Gasification - Biological or Thermal  
Conversion

# Conversion Technologies for Biomass

## Efficiency and Scale Map



# Russian Northwest Territories

## Heat and Power from Sawmill Residues

### Verkhni Ozerski - Today

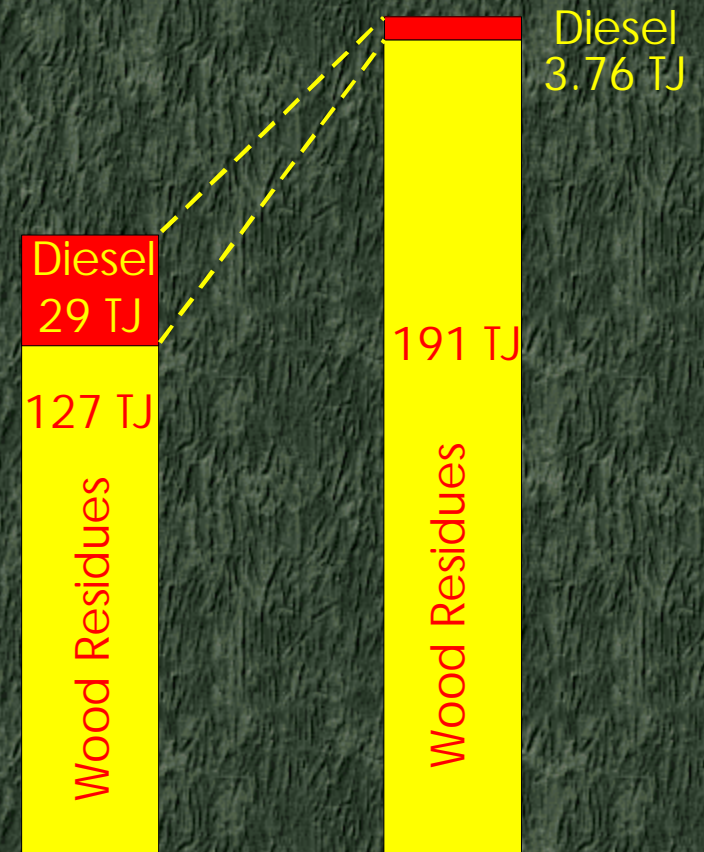
215 Households, 640 Population  
Current District Heating System and Diesel Electric  
Diesel fuel cost = 15 - 20 ¢/kWh  
Ratio of heat to electricity demand 4.5

### Proposed system

Efficient boiler to replace existing  
Steam turbine to offset 87.5% of diesel  
Cost effective on residues

Source NREL /SR-210-204040

Prepared by Ecotrade 2/98



# Power Generation

## Direct Fired

Steam Turbines and CHP Applications

- Direct biomass combustion

- Gasification close coupled to boiler or HRSG

- Steam turbine

Internal Combustion - AD gas, Low and Medium  
CV gas, Liquid Fuels

- Gas Engines with spark ignition

- Dual Fuel (with Diesel or Kerosene)

- Gas Turbines

- Fuel Cells

# Power Generation

Indirect or External Coupling

Indirect cycle gas turbine

Stirling engines

Direct fired with solid fuel

Gas fired with AD gas, Low and Medium CV gas,  
Liquid Fuels

Thermionic generators

Thermovoltaics



# Gasification - Biological a.k.a. Anaerobic Digestion (AD)

Handles wet easily hydrolyzed biomaterials

Animal residues in slurry reactors

- Chinese individual household systems
- Intensive animal husbandry - swine, chickens, dairy cows, beef feedlots

Industrial process residues

- Sugar mill effluent, breweries, distillation plants, pharmaceuticals

Municipal solid waste in landfills

## Process

Slurry based

High and low rate systems

Efficiency depends on the Resource, and Temperature

Recycles nutrients to the land

Costs are high if not justified for environmental reasons

# Biogas Product

Anaerobic Digestion/Landfill Gas

## Composition

- Methane 55-70%
- Carbon Dioxide 30-45%
- H<sub>2</sub>S 200-4000ppm

## Heating Value

- 20 - 25 MJ/Nm<sup>3</sup>

## Utilization

- Electricity via GT, Gas Engine
- Heat for Boilers

# Thermal Gasification

Scale limits choices

Simple Process Concept - Difficult to Engineer

Heat + Biomass = gas + pyrolysis oils + char + ash + steam

- Internal or External Heating
  - Internal - heat transfer and mixing
    - Counter current gasifiers (Updraft)
    - Co-current gasifiers (Down and cross draft)
    - Fluidized beds - Bubbling or Circulating
  - External Heating
    - By-product gases from charcoal kilns
    - Indirect gasifiers
      - Battelle etc

# Biogas Product

Never Clean!

## Composition (see Table)

Contains water, tars and dust

## Heating Value

15% of natural gas

## Safety

Carbon Monoxide is a toxic gas

Excess water produced - tar contaminated

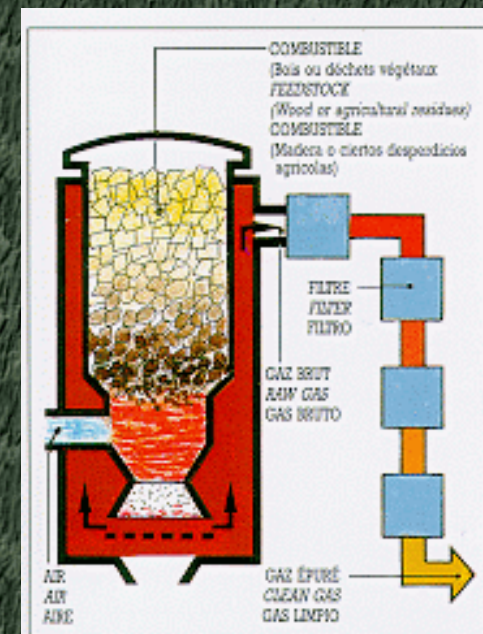
Tars contain carcinogenic PAHs

## Utilization

Close Coupled - >85% efficiency

Cold-clean gas 60 - 70% efficient

Gas	Heating Value	Percentage	Contribution
Carbon Monoxid	12.6	20.5	2.58
Hydrogen	12.8	17	2.18
Methane	39.8	2	0.79
Ethane	70.4	0.1	0.07
Ethylene	64	0.1	0.06
Nitrogen	0	49.2	0
Carbon Dioxide	0	11.2	0
Heating Value			5.68



# Commercial Gasifier Technologies

## India and China Lead in Units in Service

### India

MNES sponsored subsidy program

Leading manufacturer ANKUR has installed > 500 systems

- Moral hazard of subsidy for diesel/gas dual fuel systems
  - 10% of units continue on biomass, the rest mainly on diesel

Several manufacturers and developers

- Agroindustry acceptance good
  - Skilled personnel
  - High capacity factors
  - Available low cost residues

Typical Efficiency 18 - 20%

Costs (in country) 900 \$/kW (3.5 kW) to 400 \$/kW (100 kW)

# China

## Rice Hull Gasifiers

### Rice Hull Gasifiers

Designed for use in central rice processing facilities

120 - 150 units of about 160 kW in operation

Hongyan Motor Works 88.3 Litre gas engine (SI)

– Compression ration 8.5

– 600 rpm

Efficiency 11 - 16%

Cost (in country) 265 \$/kW (1995)

# China

## Village Gas - Distribution

### Shandong Energy Research Institute

100 and 200 Household modules

Uses agricultural residues

- Wheat straw
- Corn stover

### Gas Distribution

- Low pressure
- Plastic lines

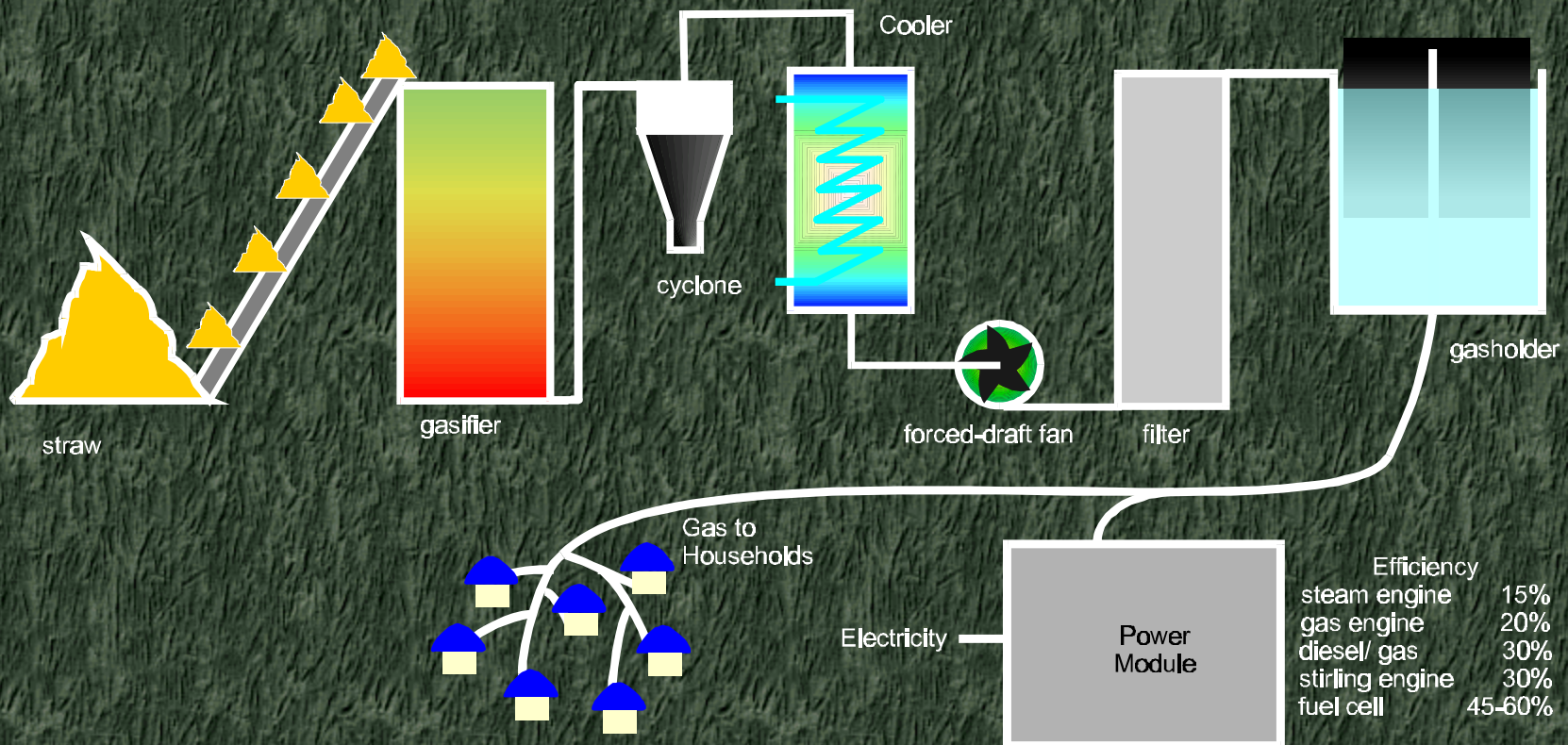
Efficiency overall 42 - 48 %

- Cold gas efficiency 70 - 75%
- Cooking efficiency 65%

Investment costs 200 \$/household

# Shandong Village Energy System

> 20 Village Demonstrations





# DOE's Small Modular Biopower Projects

To provide power in the 5 kW - 5 MW range

To develop small modular biopower systems that:

- are fuel flexible
- are efficient
- are simple to operate
- have minimum negative impacts on the environment
- are for domestic and international markets

Multi phase Project:

Phase 1: Feasibility Studies

Phase 2: Prototype Development and Testing

Phase 3: Integrated Systems Demonstration

Team Management - DOE, NREL, SNL

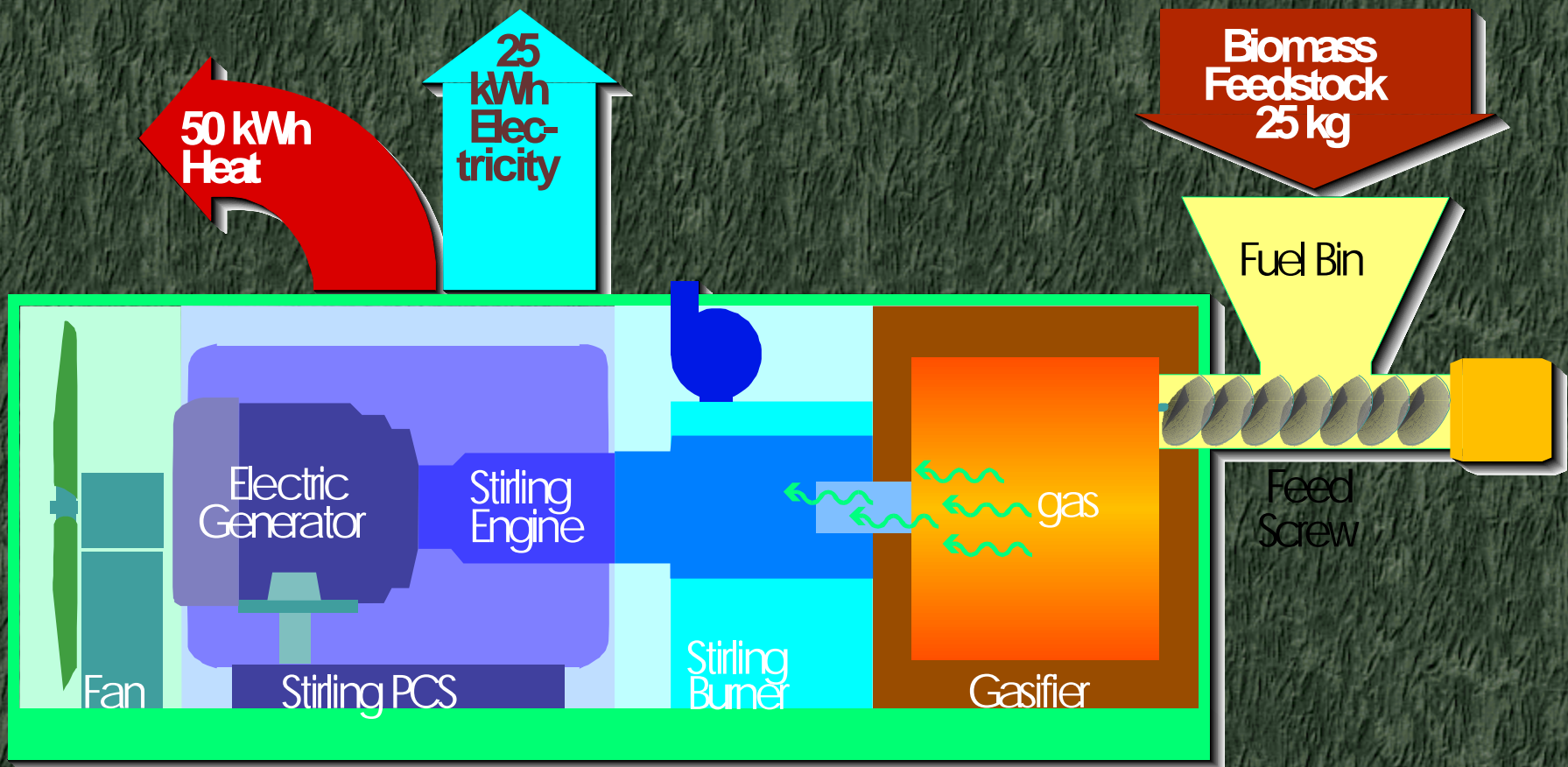
# DOE's Small Modular Biopower Projects

## Phase 1 Contracts Awarded

Agrilectric	Fluid-Bed Combustor/Steam Turbine	500 - 5000kW
Bechtel	Gasifier/Engines/Gas Turbine	500 - 1500kW
Bioten	Direct-Fired Combustion Turbine	5000kW
Carbona Corp	Gasification/ Steam Turbine	1000 - 3000kW
Community Power Corp	Gasification/IC Engine	10 - 25kW
EERC	Fluid-Bed Combustor/Steam Turbine	500 - 5000kW
Niagara Mohawk	Gasification/IC Engine/Gas Turbine	500 - 5000kW
Reflective Energies	Gasification/Gas Turbine	100 - 1000kW
STM	Gasification/Stirling Engine	25 - 70kW
Sunpower	Gasification/Stirling Engine	1 - 10kW

# Biomass fueled Stirling Engine

Proof of concept demonstrated in USA and Europe



# Innovative Turbine Concepts

## Reflective Energies

### Central Problem in Gas Compression

Requires clean gas (particle and tar free)

### Low Calorific Value Gas Combustion

Challenge to existing turbine designs

### Novel Concept

Catalytic combustion

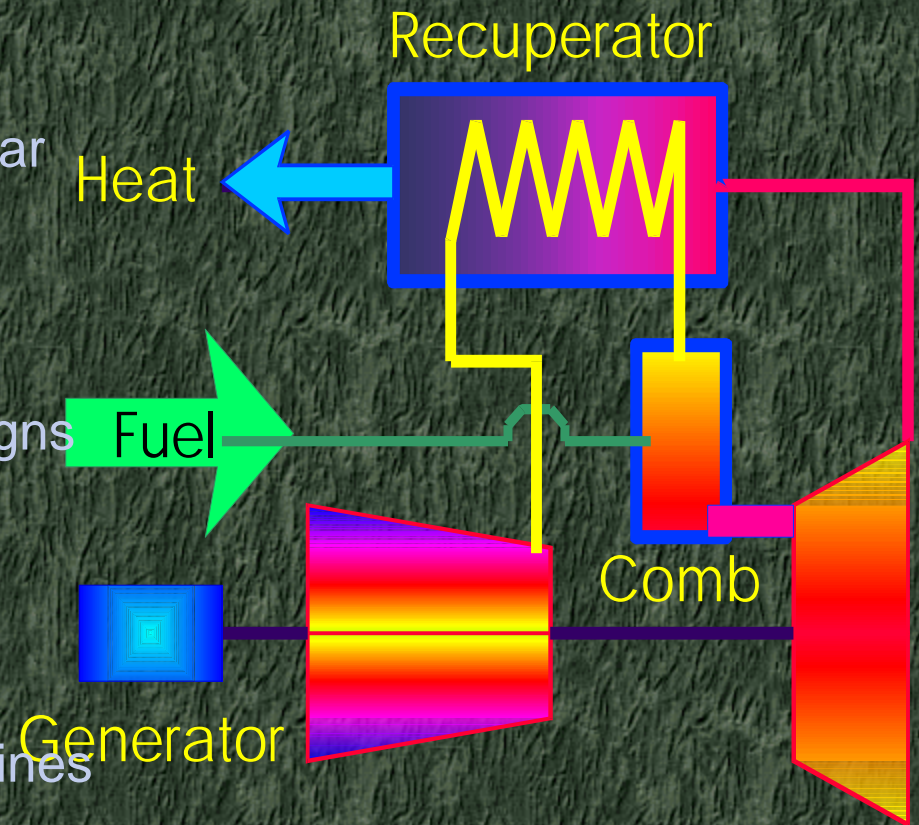
Use of turbine inlet compressor

– To compress a fuel and air mix

Applicable to a wide range of turbines

– Micro-turbines 40 - 75 kW

– Multi-MW units



# Conclusion

## Key Elements for Development

Ability to use Agricultural Residues at High Efficiency

Fuelwood declining

Ag crops increasing, Urban/Village wastes growing problem

Future Systems Have to make Productive Use of Heat

All systems are heat engines

– Turbines and Stirling concepts can produce high quality heat

Environmental Performance Improvements are Needed for  
GASIFIERS-IC Engines

Overall system performance with respect to

– Air emissions - Nox, CO and particulate

– Water emissions - particulate, tars, phenols

Advanced Technologies

Increased efficiency

Potential synergy with automotive and other developments to  
reduce costs

# Acknowledgments

The mistakes and omissions are mine!

The NREL Team: Rich Bain, Kevin Craig, Helena Chum, John Scahill, Matt Ratcliff, Esteban Chornet

The China Team: Deng keyun, Dai lin, Li jingming, Sun li, Bai jinming, Zhang zhengmin, Li jingming, Wang yaojun, Luo weihong

Thomas B. Reed (doing a gasification survey!)

Ed Gray- Antares, Stephen Brand - Thermogenics, Inc., Rob Walt - Community Power Corp., Eric Larsson, Princeton, Prof. H.S. Mukunda IIS-Bangalore, Stephen Joseph -BEST, Lennart Johansson - STM, Serge Adamian - Ecotrade, Edam Prabhu -Reflective Energies, Dean B. Mahin Consultant, Lakshman Velupillai - LSU, Pat DeLaquil -EnergyWorks, Hubert Stassen -BTG, John Black -BBC Engineering, Mark Paisley -Battelle.

Work carried out under the USDOE - OUT Power Program -Gary Burch and Ray Costello

NREL is a national laboratory of the USDOE managed by Midwest Research Institute

Contract DE-AC36-83CH10093