Status of Biomass Gasifier Village Systems

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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

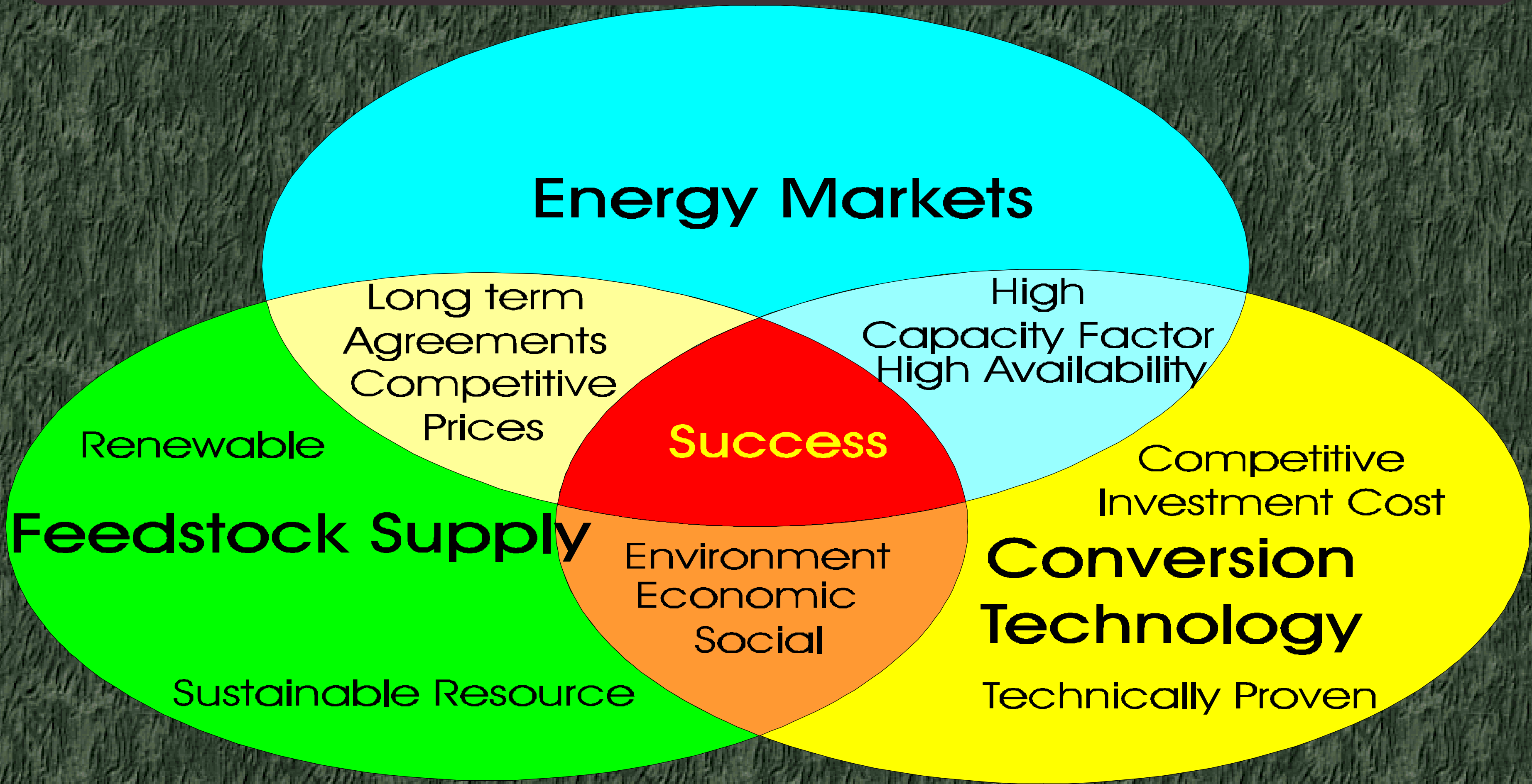
Sustainable Resources and Efficient Technologies are Needed

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



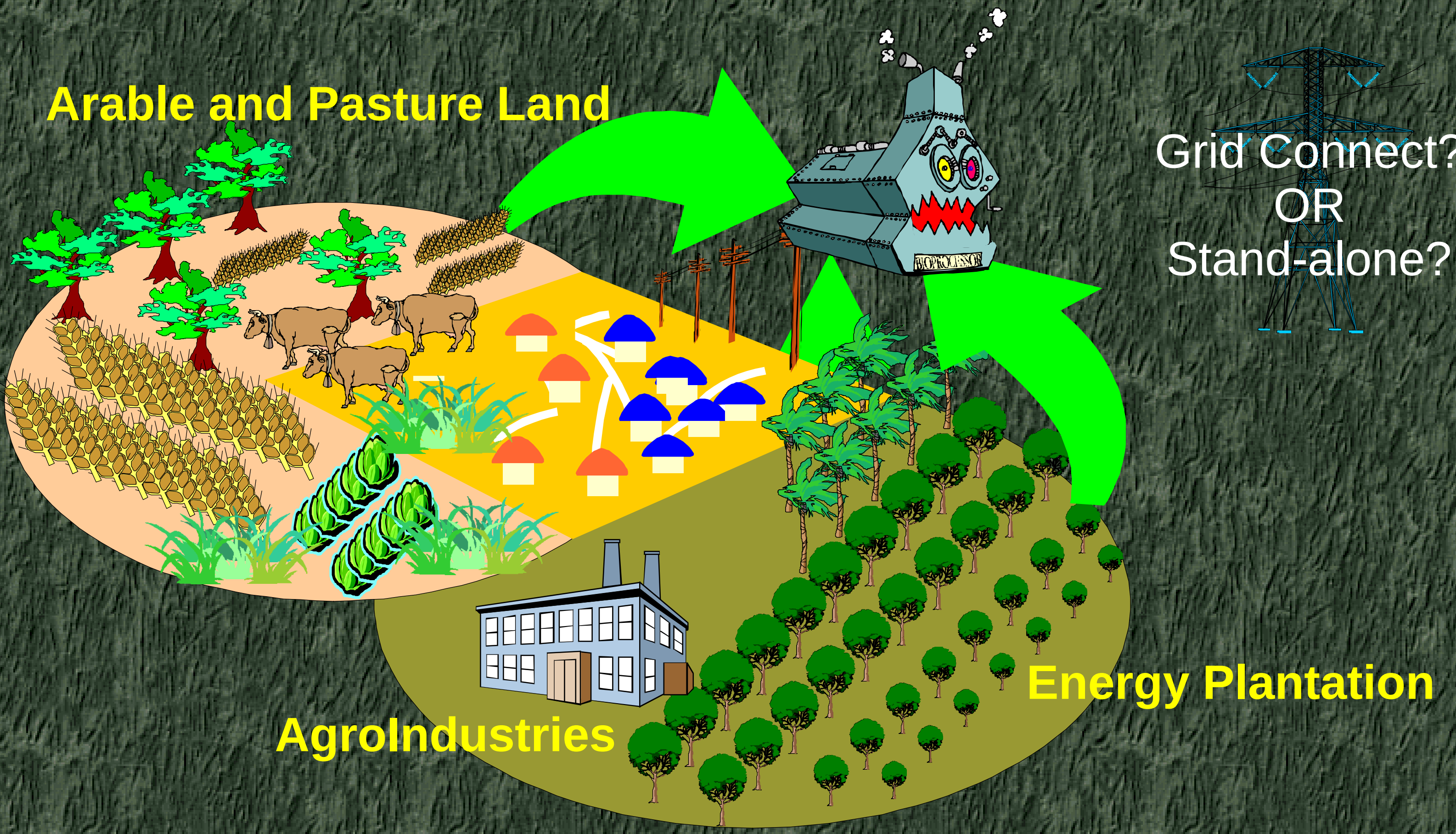
Resource Base Considerations

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

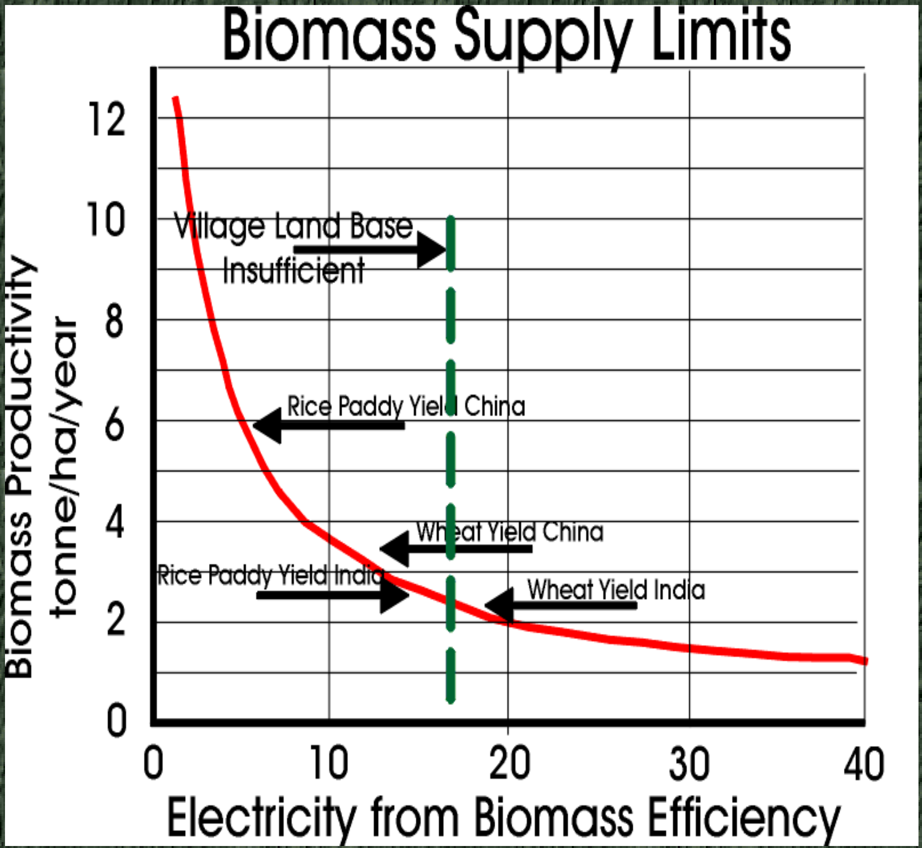
(125 kW peak)

Land Available

- 500 ha Arable Land (India)
- 70 ha of Arable land (China)

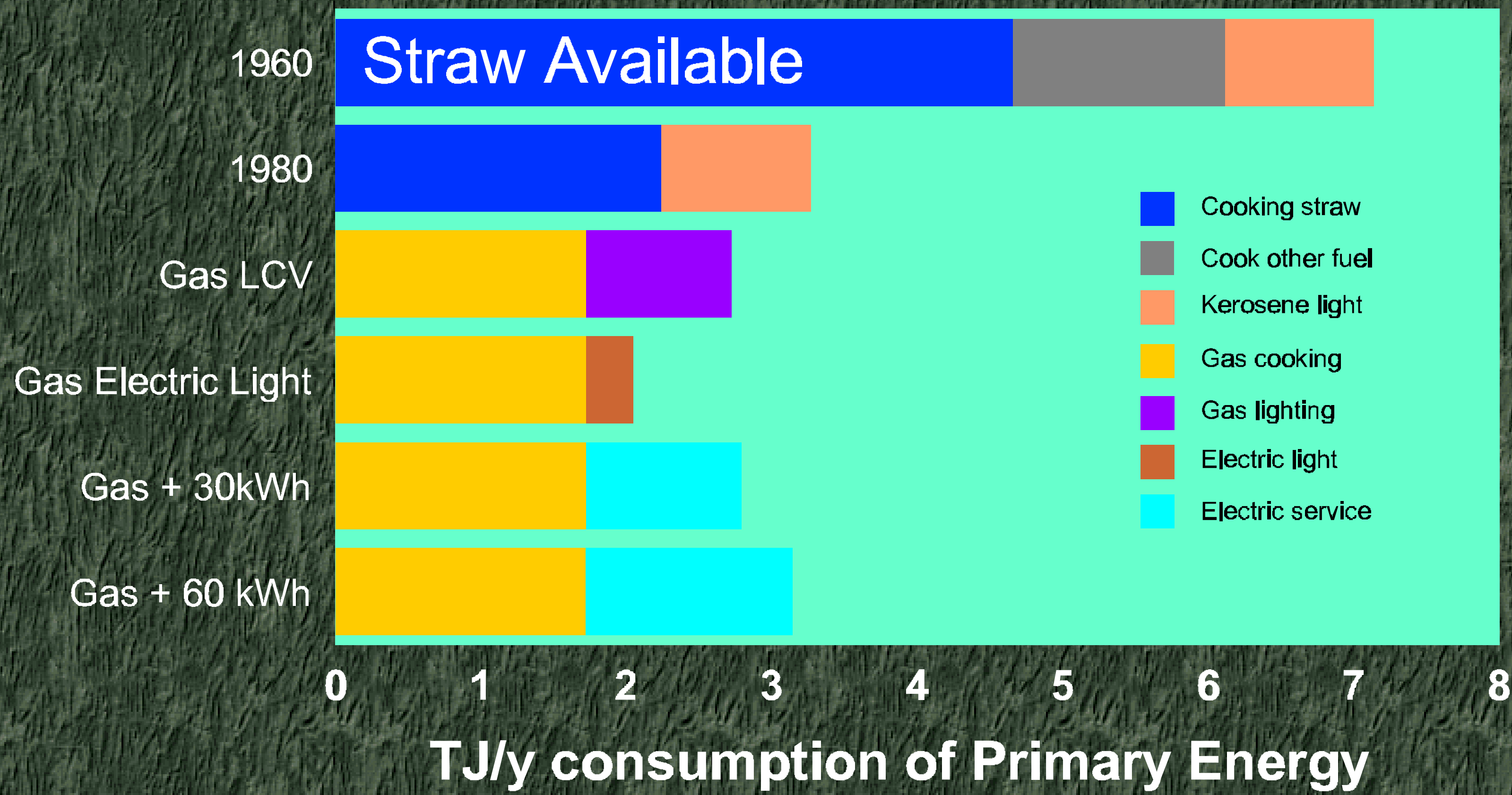
NO OTHER BIOMASS RESIDUE UTILIZATION

- Daily Living
- Animal Fodder
- Animal Bedding
- Fuel for Village Industry
- Other products - paper



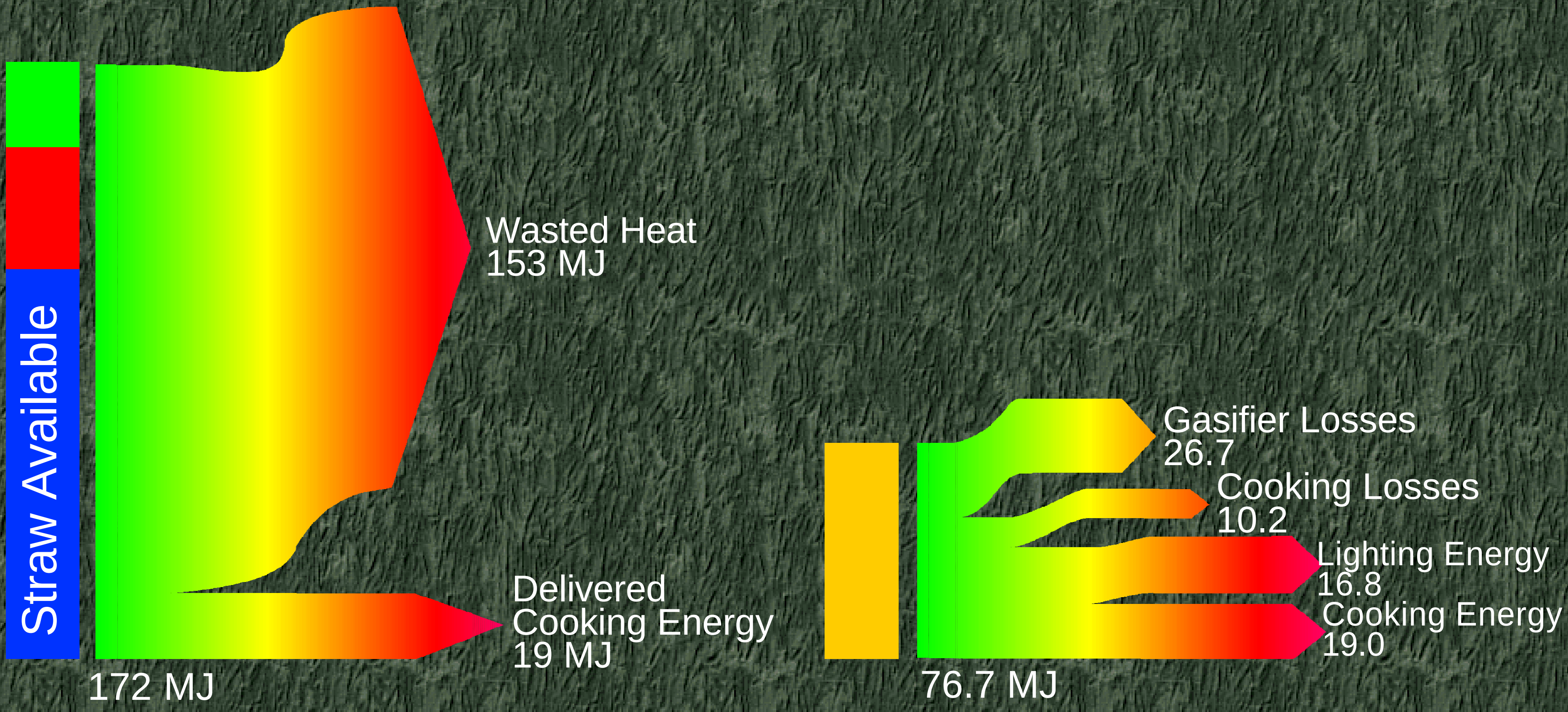
Technology Makes for Better Service

100 households 20 hA arable land - double cropped



Village Energy systems

Moving from 1960-2000



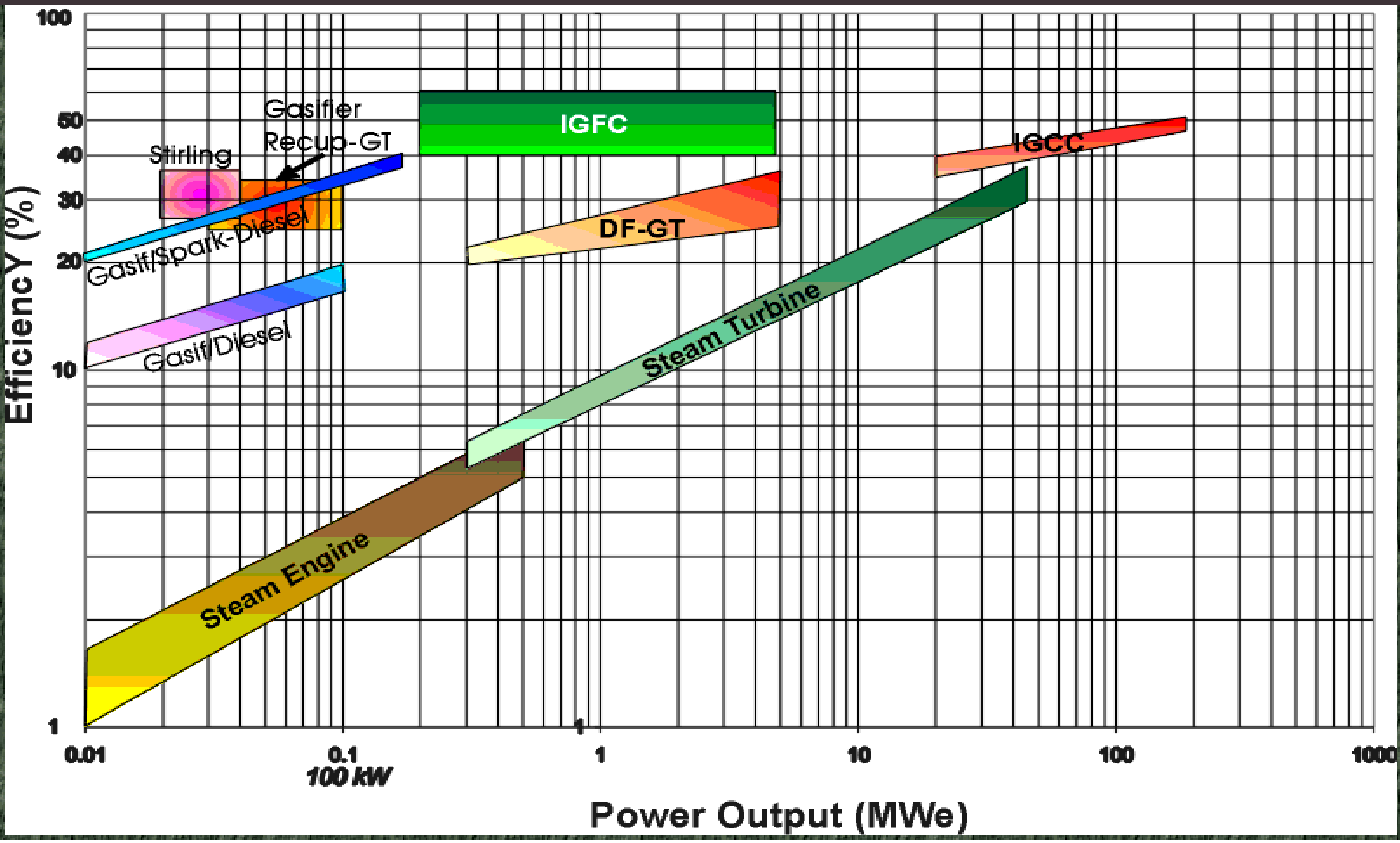
Technology Options

Biomass Pretreatment and Post Conversion

- Physical (Size reduction, slurrying, 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

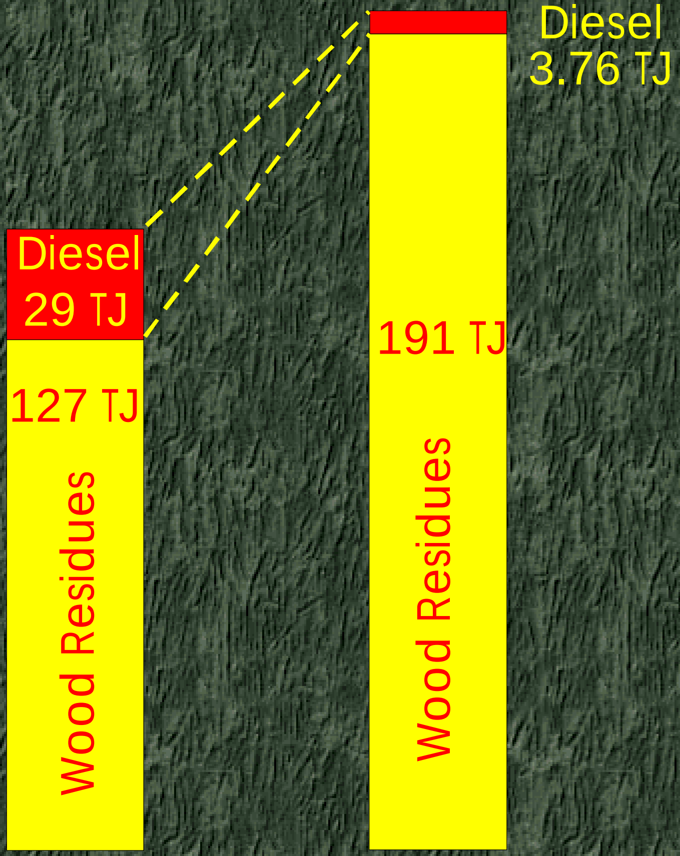
Verkhni Ozerski - Today

- 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%
- H2S 200-4000ppm

Heating Value
- 20 - 25 MJ/Nm3

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

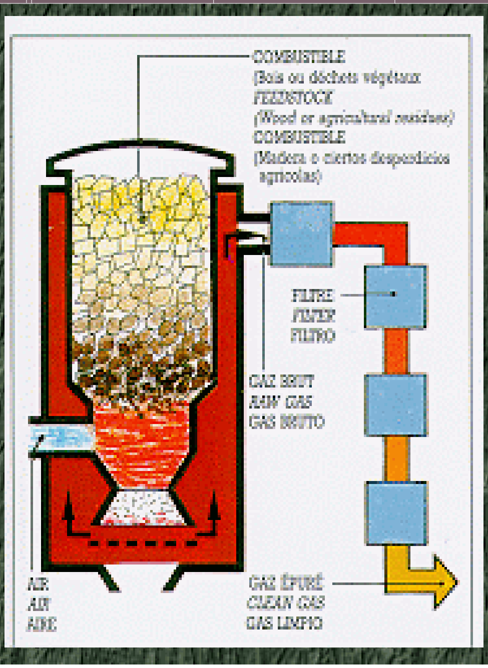
- Internal or External Heating
  - Internal - heat transfer and mixing
    - Counter current gasifiers (Updraft)
    - Co-current gasifiers (Down and cross draft)
    - Fluidized beds - Bubbling or Circulating
  - External Heating
    - By-product gases from charcoal kilns
    - Indirect gasifiers
 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

Biogas Product

Never Clean!

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

- 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



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

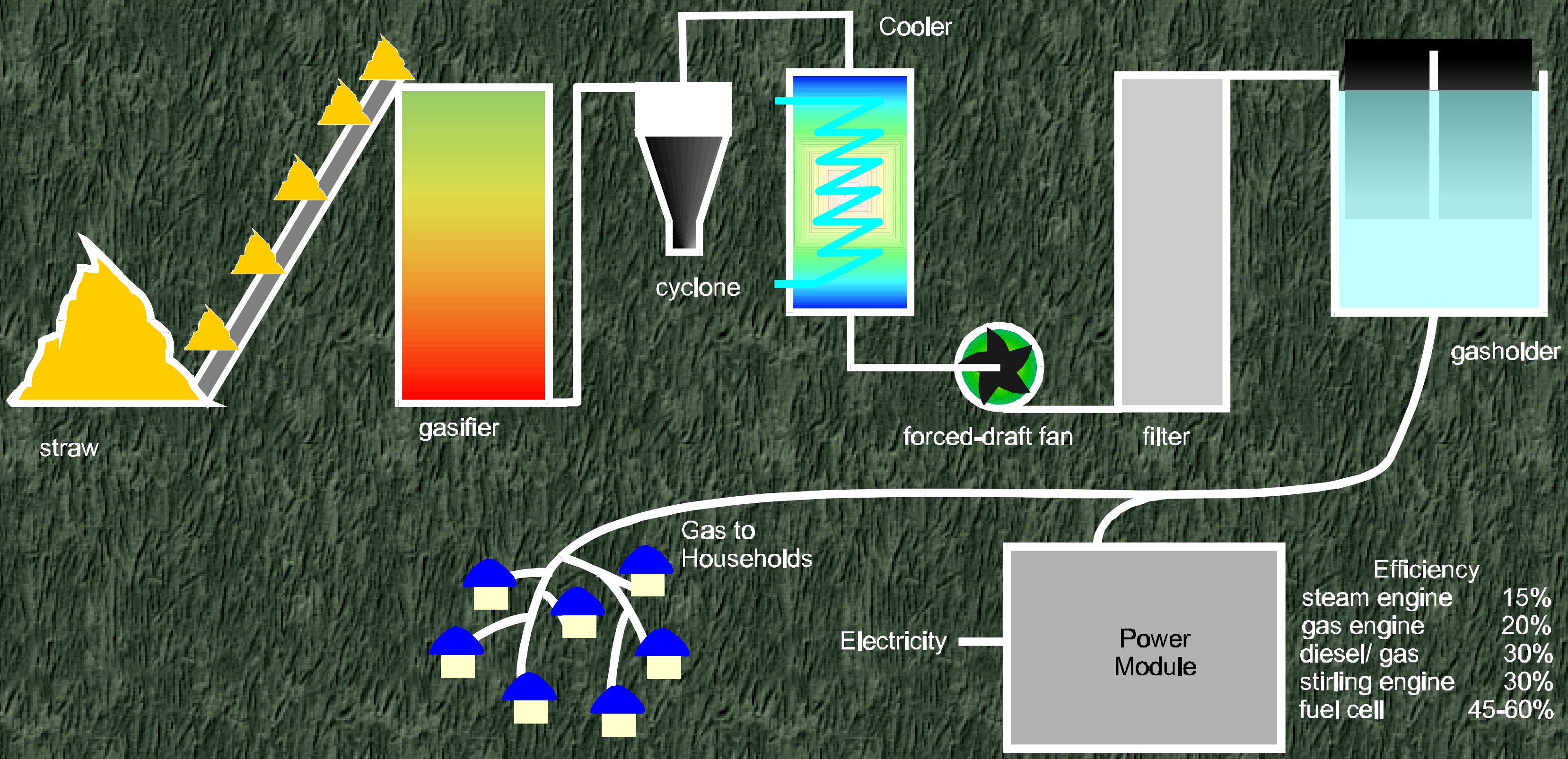
Village Gas - Distribution

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

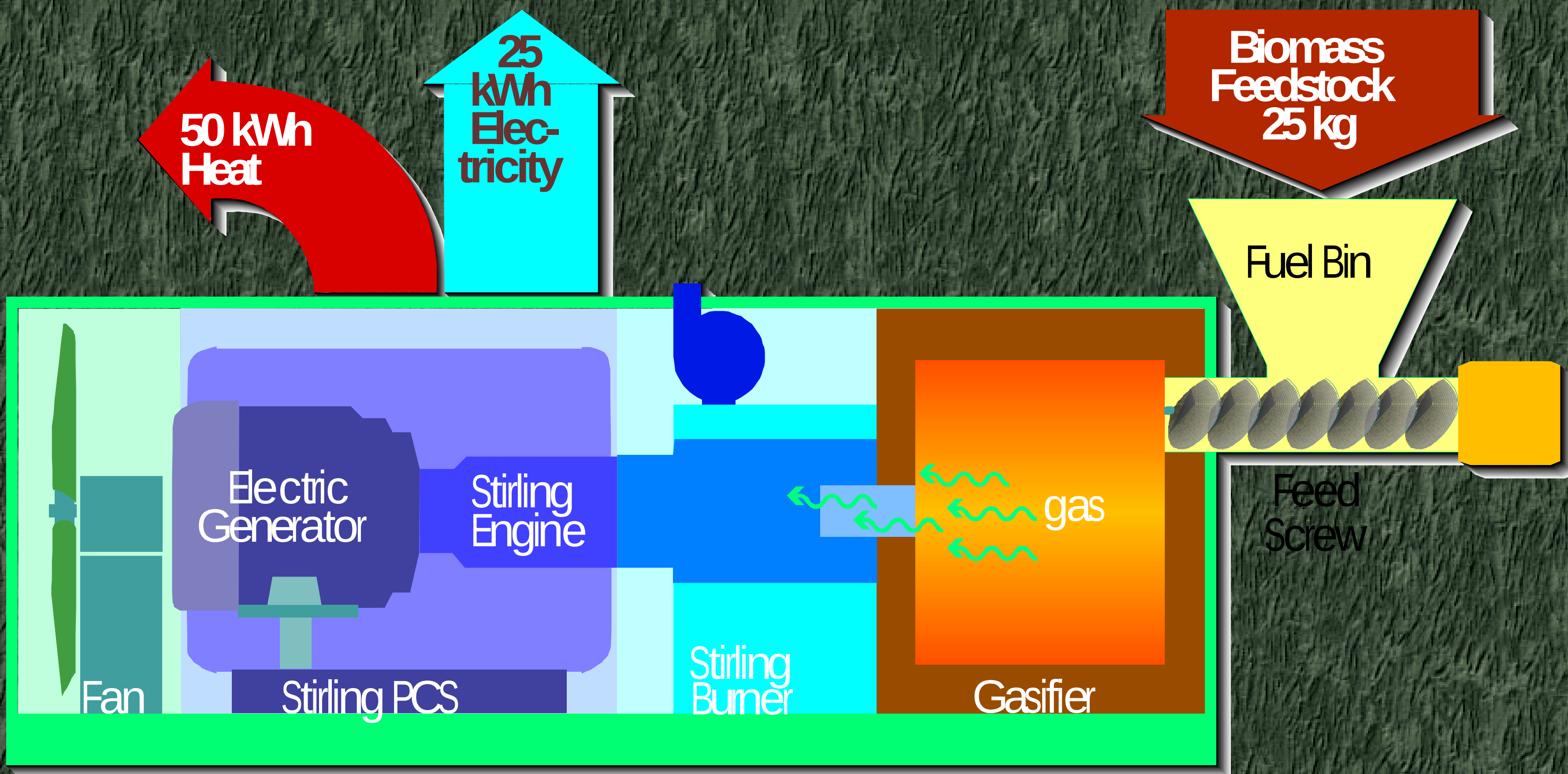
DOE's Small Modular Biopower Projects

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

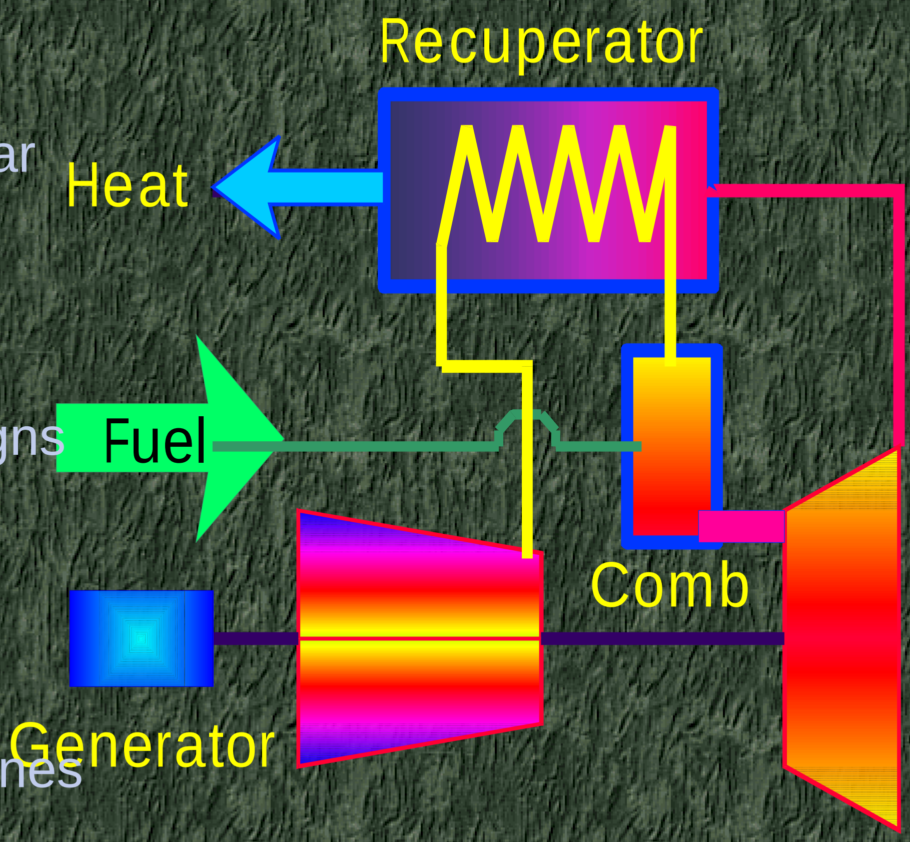
Proof of concept demonstrated in USA and Europe



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

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