Combined Heat & Power (CHP) for Iowa's Swine Industry

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What is Combined Heat and Power?

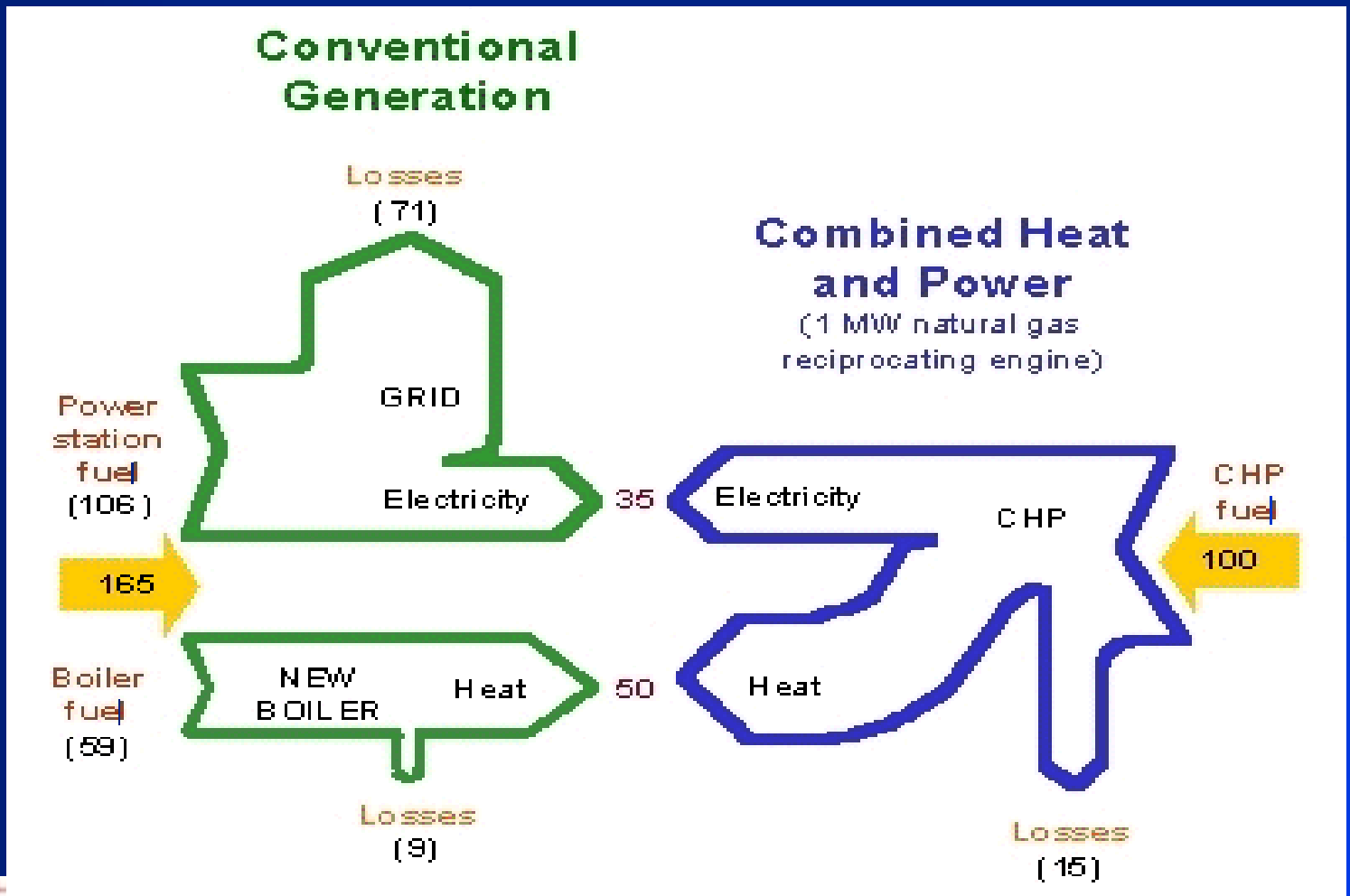
CHP is …

- **An Integrated System**
- **Located At or Near a Building/Facility**
- **Providing a Portion of the Electrical Load and**
- **Utilizes the Thermal Energy for**
  - **Process Heat**
  - **Heating**
  - **Cooling**
  - **Dehumidification**

CHP System Sizes *(Terminology)*

System Designation	Size Range	Comments
Mega	50 to 100+ MWe	• Very Large Industrial • Usually Multiple Smaller Units • Custom Engineered Systems
Large	10's of MWe	• Industrial & Large Commercial • Usually Multiple Smaller Units • Custom Engineered Systems
Mid	10's of kWe to Several MWe	• Commercial & Light Industrial • Single to Multiple Units • Potential Packaged Units
Micro	<60 kWe	• Small Commercial & Residential • Appliance Like

Conventional Generation vs. CHP



Why CHP?

High Efficiency, On-Site Generation Means …

- Competitiveness
  - Lower Energy Costs
  - Better Reliability
  - Better Power Quality
- Environmental
  - Lower Emissions (including CO_2)
  - Conserve Natural Resources
- Synergies
  - Potential Generation Asset
  - Especially Municipal/Co-ops
- Support Grid Infrastructure
  - Fewer T&D Constraints
  - Defer Costly Grid Upgrades
- Facilitates Deployment of New Clean Energy Technologies

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What Makes A Good CHP Application?

- **Coincident Needs for Power & Thermal Energy**
- **Cost of Buying Electric Power from the Grid Relative to the Cost of CHP Fuel**
  a.k.a "Spark Spread"
- **Installed Cost Differential Between a Conventional and a CHP System**

Candidate Applications for CHP

- Hospitals
- Colleges / Universities
- High Schools
- Residential Confinement
- High Rise Hotels
- Fitness Centers
- Food Processing
- Paper / Lumber Mills
- Chemical Plants
- Metal Fabrication
- Ethanol Plants
- Hog & Dairy Farms
- Landfill / Water Treatment Plants

Anaerobic Digesters

- **Natural Biological (bacterial) Process That Converts Organic Carbon From Large Molecules to Simple Molecules**
- **When Properly Applied, Digester Technology Can Effectively Assist in:**
  - **Sustainable**
  - **Economical**
  - **Environmentally Balanced**
  - **& Neighbor Friendly Agricultural Practices**

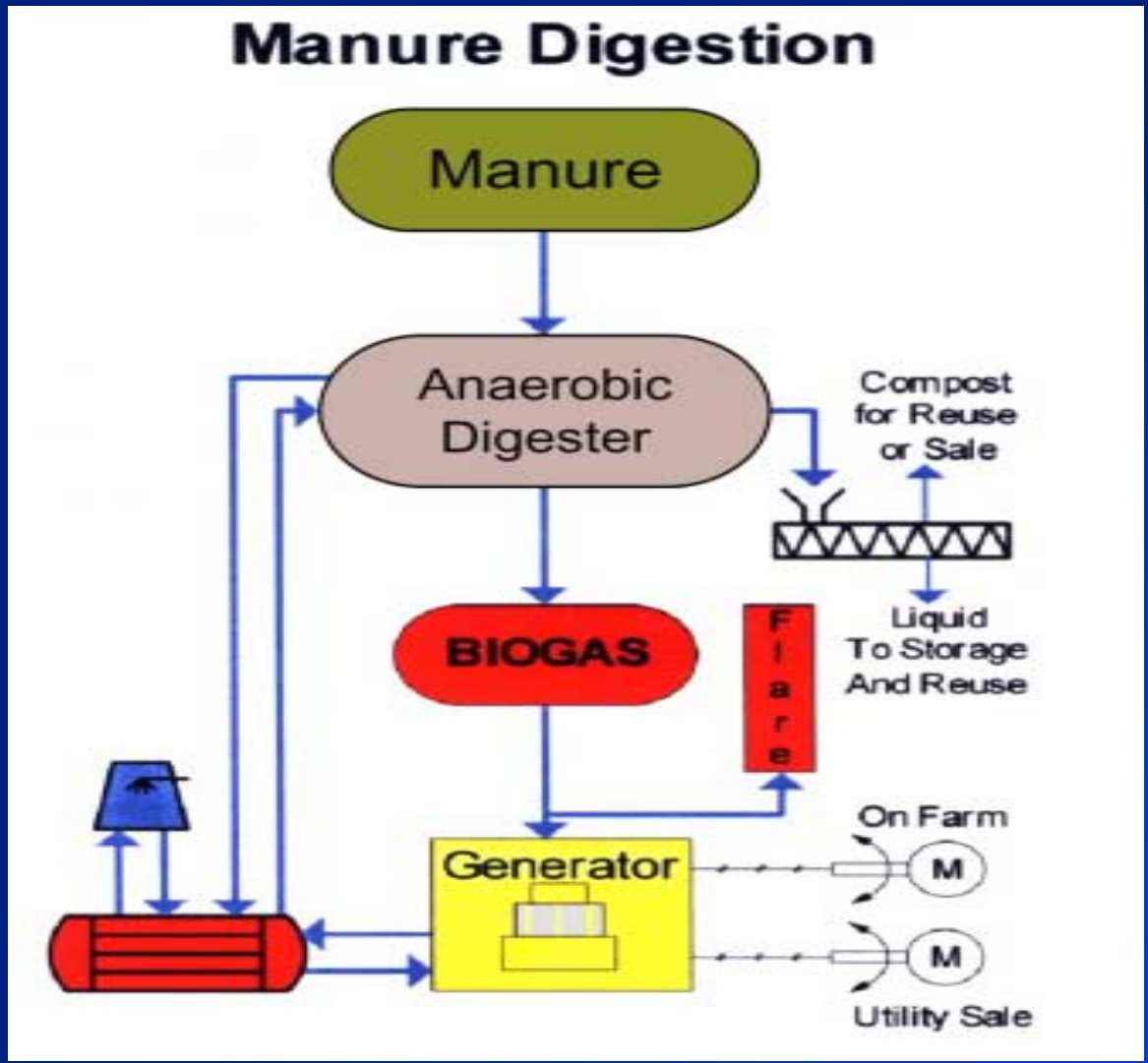
Primary Advantages of AD

- **Odor & Insect Mitigation**
- **Nutrient Management**
- **Energy Recovery**
- **Reduced Greenhouse Gas Emissions**

Energy Recovery - Biogas

- **Flare It**
- **Use It for Heating**
  - **Displace Natural Gas / Propane**
- **Use It for CHP**
  - **Displace Purchased Electricity**
  - **Displace Natural Gas / Propane**

Anaerobic Digester / CHP System



Electric & Thermal Coincidence

- **Steady Use of Recovered Thermal Energy**
  - **Heat the Digester**
  - **Heat the Livestock Operation**
  - **Heat Potable Water**
- **Steady Use for the Electricity**
  - **Displace Electricity Utilized on the Farm**
  - **Possibly Sell Excess Electricity to Utility**

Some Misconceptions

- **Need to Sell Excess Electricity Back to the Utility to Make CHP Profitable**
- **Need to Have Emergency Generator Sets In Addition to the CHP System**

Concepts

- **Grid Interconnection**
  - **Induction vs Synchronous**
- **Sizing the CHP System**

Grid Interconnection

Induction Systems

- Less Complicated & Potentially Less Costly to Interconnect
- When Grid Goes Down, CHP System Goes Down
- Need Emergency Gen. Sets

Synchronous Systems

- More Complicated & Costly to Interconnect
- With Proper Protective Relays – CHP System Can Continue to Operate Reliably & Safely Thru Blackouts & Brownouts.
- Grid Serves as Backup to CHP – CHP Serves as Backup to Grid
- Depending on CHP Size / Configuration, May Not Need Emergency Gen. Set

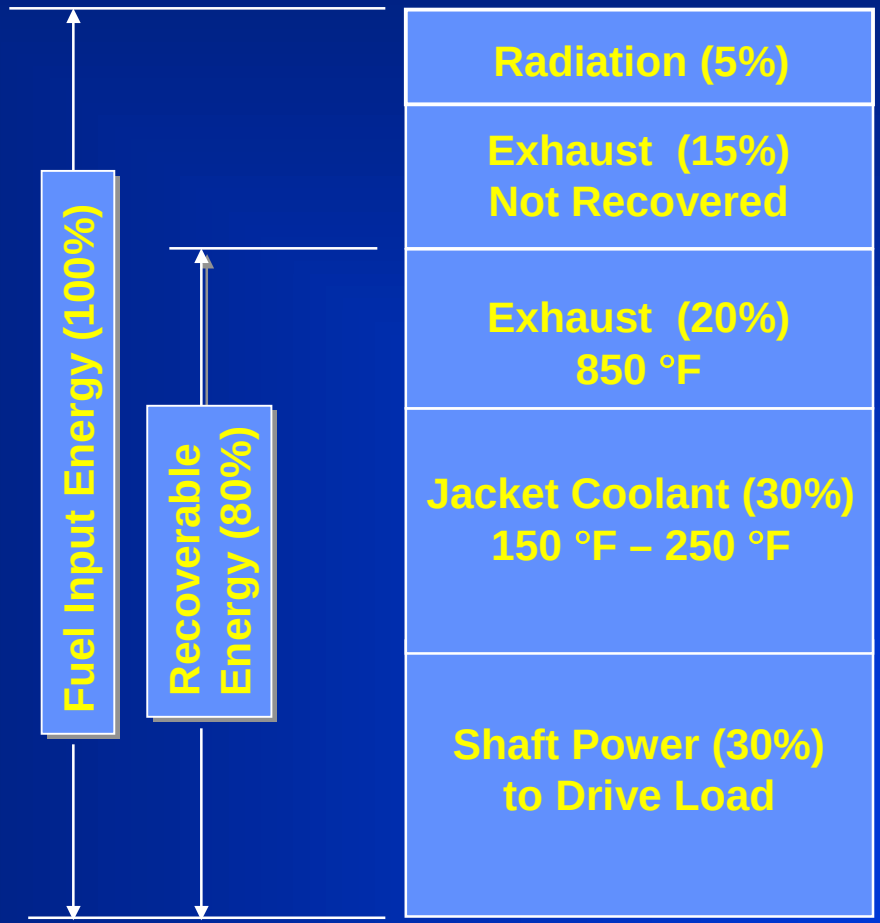
CHP Technologies

- **Prime Mover**
  - Reciprocating Engine
  - Micro-Turbine
  - Gas Turbine
  - Fuel Cells
- **Heat Recovery**
  - Hot Water
  - Steam
  - Direct Exhaust
- **Thermally Activated**
  - Absorption Chillers
  - Desiccant Dehumidifiers
- **Other Equipment**
  - Controls
  - Interconnect

Reciprocating Engine Characteristics

- **Low Capital Cost / Proven Reliability**
- **Easy Start Up / Good Load Following**
- **Significant Heat Recovery (Exhaust & Cooling Jacket)**
- **Typical Power Range: 5 kW to 10 MW**
- **Efficiency Range (< 500 kW): 25% to 30% (heat rates of 14,000 to 11,500 btus/kWh)**

Reciprocating Engine - Heat Balance

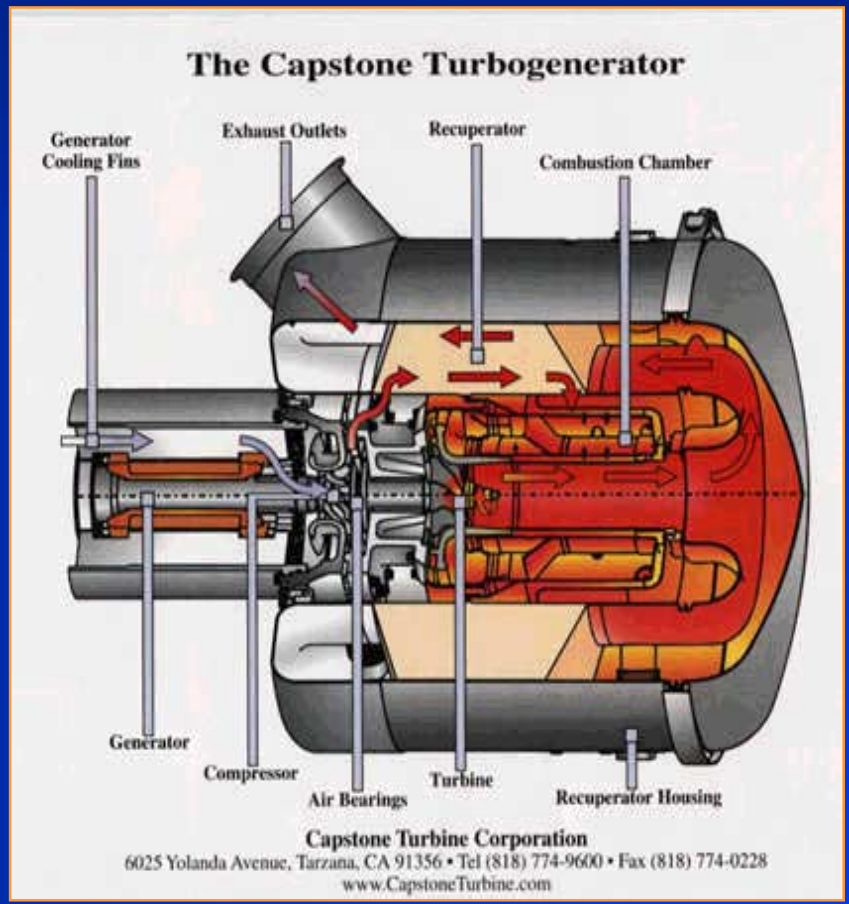


Rules of Thumb (Recip. Engines <500kW)

- **Recoverable Useful Heat:**
  - **Hot Water --- 4,000 to 5,000 Btu/h per kW**
  - **15 psig Steam --- 4 to 5 lbs/h per kW**
- **O&M Costs:**
  - **$0.012 to $0.015 per kWh**
- **Installed Costs:**
  - **$1,400 to $1,800 per kW (with heat recovery)**

Microturbines

- **Consist of a compressor, combustor, and turbine**



Micro-Turbine Technology

Advantages

- High reliability
- Low emissions
- Fuel flexibility
- Compact and modular design
- Low maintenance
- Quick start
- Ease of operation

Disadvantages

- Requires high pressure gas
- Difficulty in following large load transients
- Performance sensitive to:
  - Inlet air temperature
  - Altitude
- Early market stage

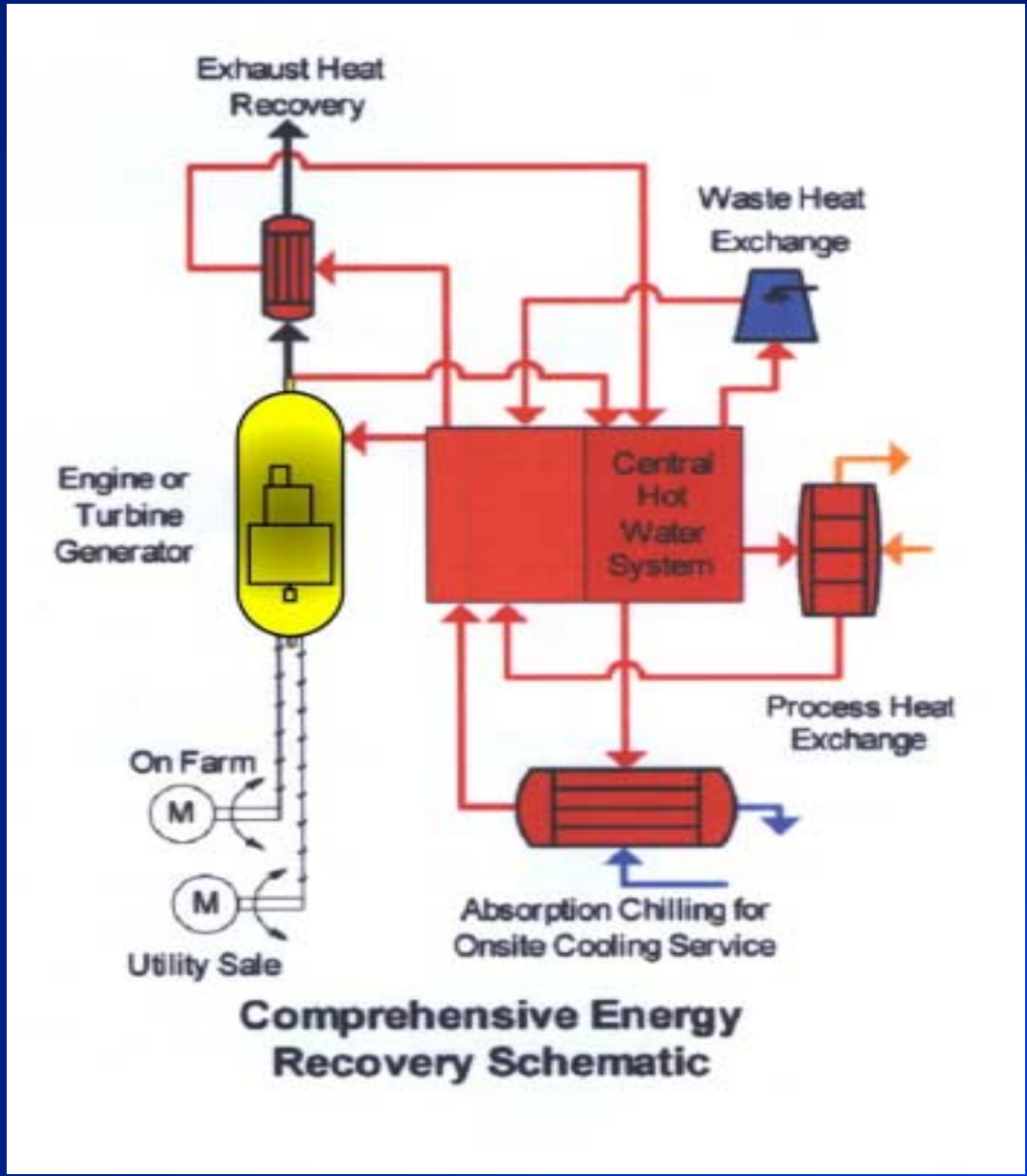
Microturbine Rules-of-Thumb

Capacity Range *(kW_e)*	30 to 400
Electrical Efficiency	25% to 30%
Recoverable Useful Heat *(Btu/h per kW_e)*	6,000 – 7,000 *(Hot water @ 160 °F)*
Installed Cost *(per kW_e)*	$1,000 to $2,000 *(with heat recovery)*
O&M Cost *(per kWh)*	$0.015 to $0.01
NO_x emissions *(per kWh)*	< 0.00049 lbs *(or 0.9 ppm)*
Heat Rate *(per kWh)*	13,700 - 11,400 Btu
MTBO	40,000 hours +
Heat Recovery Temperature	~500°F

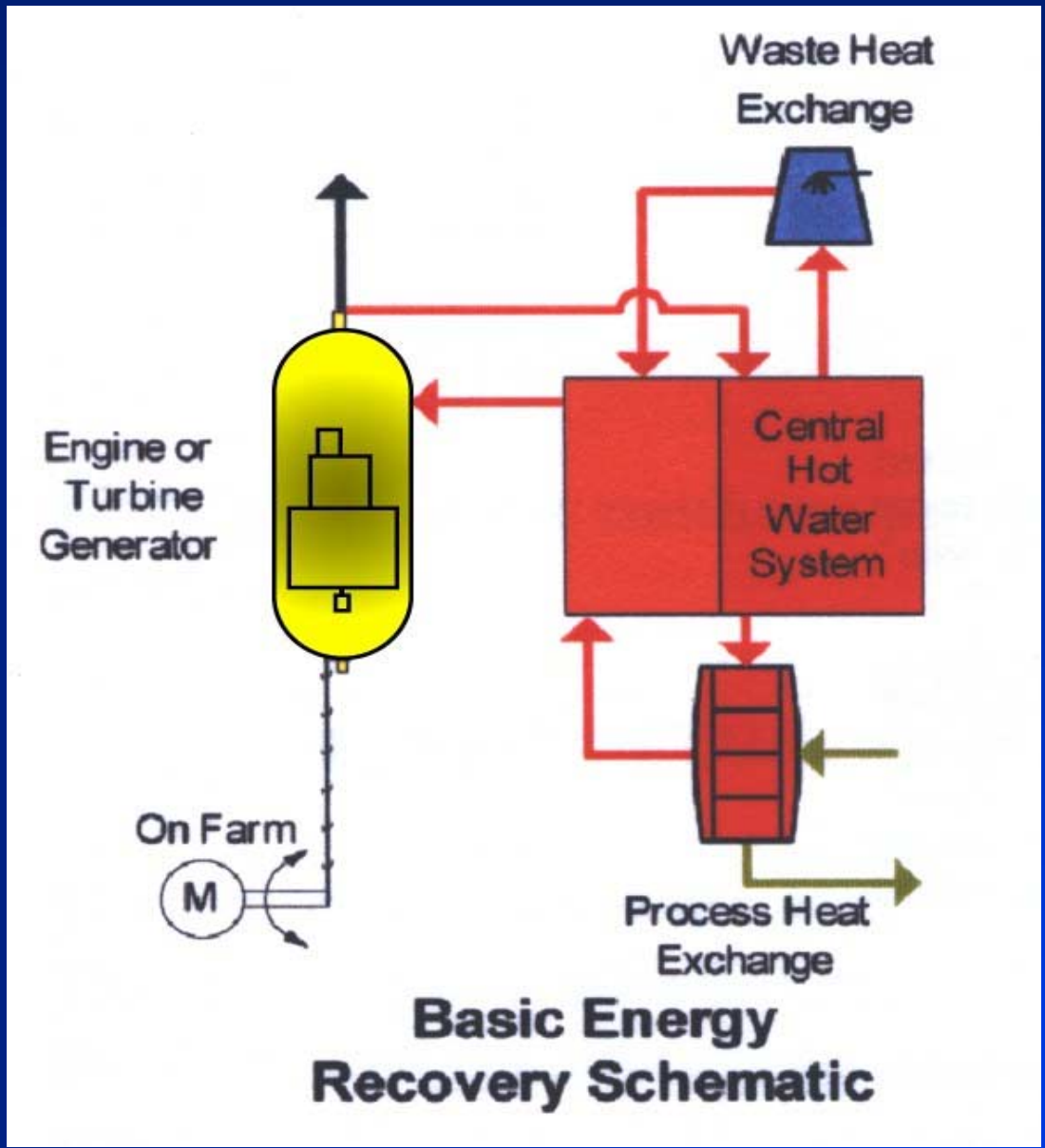
Summary Messages

- **Combined AD/CHP System (if properly designed, installed, and maintained) Will:**
  - **Improve the economics & meet odor and water requirements of the farm operation**
  - **Turn a farm operational cost (waste product) into a revenue resource**
  - **Boost the "bottom line" of the farm operation**
  - **Be a better neighbor and friend of the environment**

CHP Regional Resource Center



Comprehensive Energy Recovery Schematic



Basic Energy Recovery Schematic