Research in Alternative Energy Generation

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StarRotor
Technologies

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StarRotor Compressor Technology

Inlet

Outlet
StarRotor Expander Technology

Inlet

Outlet
Electricity Storage
Pipeline Pressure Recovery

Natural gas from high-pressure pipeline

StarRotor expanders

Natural gas to low-pressure distribution

Inter-warming heat exchangers
Waste Heat Recovery

StarRotor expander

Generator

Condenser

Boiler

Pump

Rankine Cycle Power Generation

Waste Heat
Solar Thermal Engine

[Diagram showing the components of a solar thermal engine, including:
- Solar Collection and Thermal Storage System:
  - Parabolic trough solar collector
  - Thermal storage tank
- Rankine Cycle Power Generation:
  - Electric generator
  - StarRotor Expander
  - Condenser
  - Pump]

Rankine Cycle Power Generation

Solar Collection and Thermal Storage System
\[ \eta_{\text{comp}} = \eta_{\text{exp}} = 82\% \]

\[ \downarrow \]

\[ \eta_{\text{engine}} = 57 - 66\% \]
StarRotor Engine Properties

- High efficiency (57-66%)
- Low pollution
- Low maintenance
- Low cost
- High power density
- Negligible vibration
- Multi-fuel
Biomass Thermal Conversion Research at BAEN

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The pyrolysis setup used for cotton-gin trash. (A) Purge gas (N2), (B) Gas flow meter 1, (C) Digitally-controlled furnace, (D) tar/moisture trap, (E) Condenser, (F) Thermocouple reader, (G) Liquid collector, (H) moisture trap, (I) Gas flow meter 2, (J) Sampling/exhaust port, and (K) Gas analyzer.
BAEN Gasification Teaching and Research Facilities

Skid-Mounted Gasifier

Continuous Production of Combustible Gas

Development of Control System for Gasifier

Gasifier Temperature Profile

Mobile Gasifier

Electrical Power Production System using MSW in TAMU Gasifier
**Vision for Future MSW/Household Refuse Applications**

**MSW Collection and Segregation System**

- **Household Refuse**
  - **Metals/plastic Separator**
    - **Combustible Refuse Only**
    - **Noncombustible Refuse**

- **Recycled Water**

- **Drying and Pelleting**
  - **Biomass Pellets (10% MC)**
  - **Note: Propane burner only used during start up**

- **Grid-Tie System**
  - **Generator**
  - **Engine**
  - **High quality synthesis gas**
  - **Heat Exchanger**
  - **Gas Cleanup**
  - **Cold Air**
  - **High quality synthesis gas**

**Power Generation**

- **Grid-Tie System**
  - **Generator**
  - **Engine**
  - **High quality synthesis gas**

**Note:** Propane burner only used during start up.
Electrochemical Energy Storage and Conversion Research

Energy and Transport Sciences Laboratory (ETSL)

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Lithium-ion Battery

Issues
- Lithium-ion battery performance, durability, safety
- Battery thermal management
- Materials-transport interaction
Lithium-ion Battery

Small length scale
• Simple code
• Lots of data

Large length scale
• Complex code
• Less data
Lithium-ion Battery

Model showing effects of nanocrystallites on packing density for LiFePO$_4$ cathodes.

Lithium diffusion induces stresses and fractures in active particles causing mechanical degradation of battery

Lithium-ion Battery

Influence of electrode microstructures on impedance

Polymer Electrolyte Fuel Cell

HOR – hydrogen oxidation reaction (anode)
ORR – oxygen reduction reaction (cathode)

C-supported Pt-catalyst

ionomeric electrolyte (e.g., Nafion)

Issues

• PEM fuel cell performance, durability
• Water and thermal management
• Interaction of microstructure – transport – performance
Polymer Electrolyte Fuel Cell

Porous electrodes for gas diffusion

Effect of water blockage on catalyst layer

DNS – direct numerical simulation
EXP – experiment

Polymer Electrolyte Fuel Cell

Water transport in catalyst layer

Redox Flow Battery

Features:
- Independently control power and energy
- Scalable
- Safe operation
- Low maintenance
- Long life (>10,000 cycles)

All Vanadium Redox Flow Battery

At -ve Electrode:

\[ V(III) + e^{-} \xrightleftharpoons{\text{charging}} \xleftarrow{\text{discharging}} V(II) \]

At +ve Electrode:

\[ VO^{2+} + H_2O \xrightleftharpoons{\text{charging}} \xleftarrow{\text{discharging}} VO_2^+ + 2H^+ + e^{-} \]
Redox Flow Battery

Comparison of simulation with experimental data

Charge-discharge behavior

Reservoir concentration

Cell concentration

Effect of flow rate

Effect of reservoir vanadium concentration

*Sum and Skyllas-Kazacos, J. Power Sources, 15, 179 (1985)
*Sathisha, Dalal, Mukherjee (2013)
Redox Flow Battery

Ion concentrations during charge and discharge

*Sum and Skyllas-Kazacos, J. Power Sources, 15, 179 (1985)
*Sathisha, Dalal, Mukherjee (2013)
Redox Flow Battery

Impact of operating parameters

Charge-discharge behavior

Reservoir concentration

Cell concentration

Effect of flow rate

Effect of reservoir vanadium concentration

*Sum and Skyllas-Kazacos, J. Power Sources, 15, 179 (1985)
*Sathisha, Dalal, Mukherjee (2013)
Integrated Nuclear Energy Systems

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# The Potential of Nuclear Energy

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Unique Property of Nuclear Energy
Unique Property of Nuclear Energy

Extended autonomy from fuel supplies
Unique Property of Nuclear Energy

Extended autonomy from fuel supplies

- Remote power
- Space power
- Decentralized power
System Integration and Nuclear Technology

LWR – light water reactor
SMR – small modular reactor
VHTR – very high temperature reactors
FR – fast reactors
HLW – high-level waste

H₂O – water desalination
Q – process heat
H₂ – hydrogen energy carrier
III+ – Generation 3+
IV – Generation 4
Variety of designs and integration options

NGNP – next generation nuclear power
VHTR – very high temperature reactors
DB – deep burn
LWR – light water reactor
FR – fast reactor

OTTO – once through then out
LEU – low enriched uranium
TRU – transuranics
MOX – mixed oxide

Environmentally Benign
Sustainable Energy Systems
Advanced system analysis and optimization

High-Fidelity System Analysis
Energy and efficiency

Commercial Reactors

Light Water Reactor

600 K

Thermal Efficiency
35%

300 K

POWER

LOSS
65%

Heat Cycle: Rankine Steam Cycle
Steam ... ~ 600 K
Carnot Efficiency Limit ... ~ 50 %
Energy and efficiency

Commercial Reactors

Light Water Reactor

- Thermal Efficiency: 35%
- Loss: 65%
- Power: 300 K
- High Temperature Gas-cooled Co-generation System

Future Reactors

- Heat Cycle: Direct Brayton Cycle (Helium Turbine)
- Helium: ~1300 K
- Loss: 30%
- Carnot Efficiency Limit: ~77%

Heat Cycle: Rankine Steam Cycle
- Steam: ~600 K
- Carnot Efficiency Limit: ~50%

- Thermal Efficiency: ~70%
Advanced energy technologies and systems

Direct energy conversion

- Canonical magnetic collimators
- “Venetian blind” systems
- Magnetohydrodynamics

Potential to convert 90% of nuclear energy to useful forms

FF – fission fragment
FP – fission product
Advanced Small Modular Reactors (SMR)

Products

Electricity
Potable water
Process heat

Modularity, adaptability and performance
Modeling, experimentation and demonstration

Emulation of SMR conditions in existing research reactors
Opportunities for collaboration in energy:

- Production
- Conversion
- Storage
- Integration
- Control