Importance of Energy Service Demand Representation to Consideration of Range of Technology Choices in Manufacturing

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A Critical Observation. . . .

- Energy service demands don't always equate with energy end uses
- Confusing the two in economic policy models – especially when improperly representing services demand as energy end-uses – may significantly limit the representation for cost-effective improvements in energy efficiency
- Instead of an efficiency gap of perhaps 15-25% when modeled as energy end uses, we may see a factor of 2 or greater efficiency gap depending upon technology choices

Overview of Presentation

- Review typical representations of manufacturing energy use in energy models
- Discuss the relevance of energy service demands
- Develop an example for the Food Products industry
- Link energy services to energy resources
- Discuss implications of an alternative mapping and/or representation

Introduction

- Appropriate representation of energy service demands is critical to understand productivity gains and energy efficiency opportunities
- Current models unnecessarily limit technology choices
- Critical need to understand shifts in technology <u>and</u> service demands
- Use of the food products industry as an exploratory example

Two Key Definitions

- An energy service demand is the need for a specific level of work or activity to be performed
- An energy end-use refers to a specific form (including quantity and quality) of energy used to satisfy an energy service demand
- An energy service demand does not necessarily equal an energy end use.

Illumination Service Demand vs. Lighting End Use

- Lighting end use:
  - Electricity going to lighting equipment
- Illumination service demand:
  - Can use electric lights (10% Eff) or day-lighting (∞%)
  - Illumination can actually be broken into sub-uses:
    - “Ambient” for general vision and safety
    - “Task” with high-quality for visually critical tasks
    - “Area” largely for safety in yards and warehouses

Electric Motor End-Use vs. Drive Power Service Demand

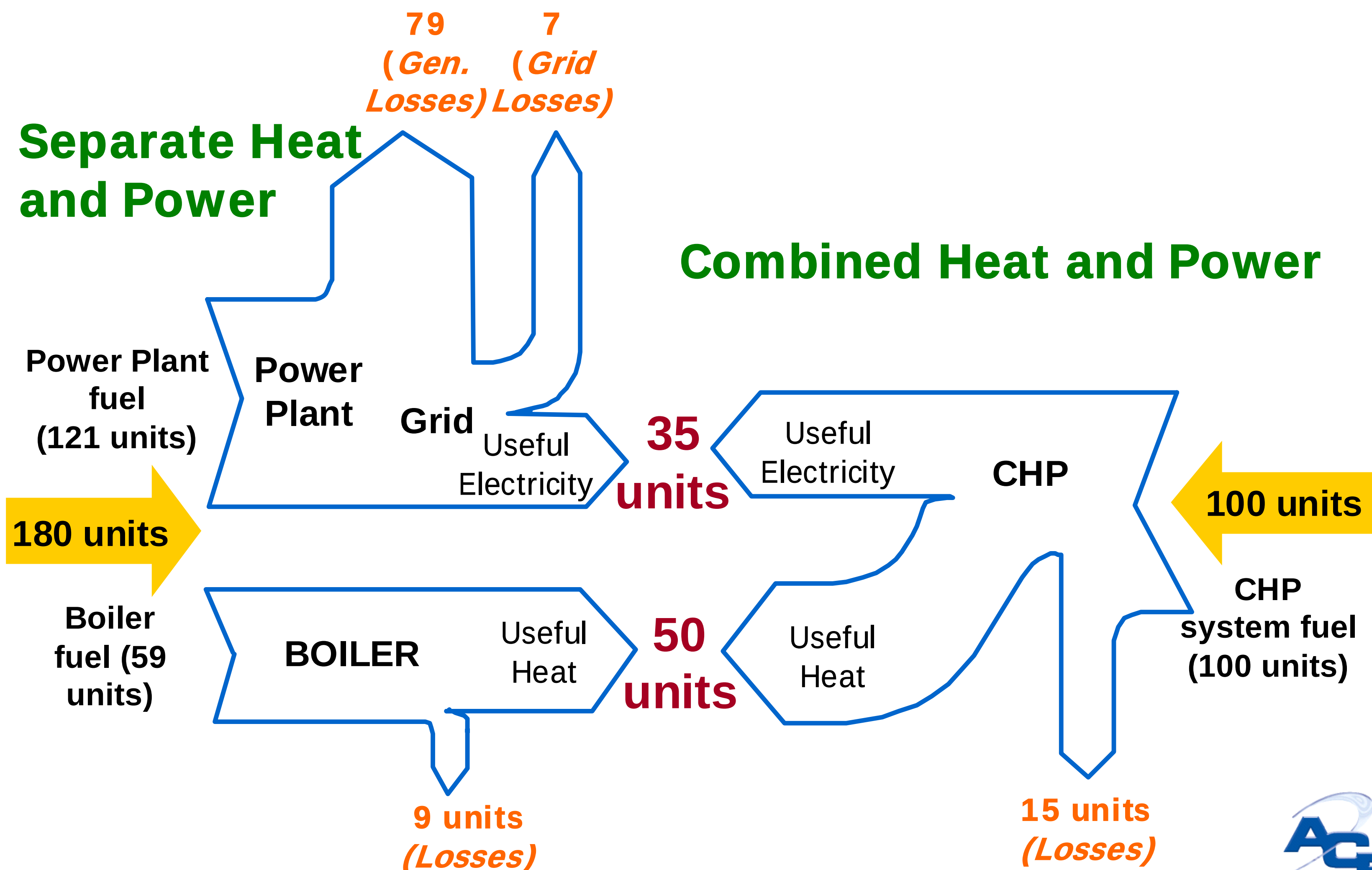
Electric Motor End-Use	Drive Power Service Demand
Compressed air	Fluid flow
Refrigeration	Conveyance
Drive power	Grinding/machining/mixing

Drive power can be satisfied by an electric motor, compressed air motor, steam turbine, or combustion engine.

Relative "Efficiency" of Delivered Drive Power by Technology

- Difference between current and "advanced" electric motor efficiency 12%
- Current delivered drive power efficiency:
  - Electric motor = ~25%
  - Combustion Engine = ~30% (22% difference)
  - CHP system = ~75% (200% difference)
- Technology choice more important than technology advances within technology

CHP or Cogeneration



Characterization of Industrial Energy Use in Models

- As part of this exercise, reviewed major economic policy models with detailed manufacturing representation and found:
  - Don’ t cleanly define service demands
  - Confuse energy use with service demands
  - Reflect a limited range of technologies for service demands
  - Energy options (e.g., CHP) are not fully integrated within those models
  - Reflect only limited fuel switching options

Challenges Representing Manufacturing Energy Services in Economic Models

- Diversity of energy uses in manufacturing
- Complex structure of sector – linked suppliers
- Process focus of energy usage
- Limited data availability on energy use and technology representations
- Fuel-switching complicated (e.g., main opportunity presented between boiler fuels – not electric to fuels)
- Inability to deal with purchased electricity displaced by fuels

End-Uses vs. Service Demands

Most economic policy models inappropriately confuse end-uses with service demands. Examples include:

- –Compressed air
- –Steam
- –Process cooling
- –Motors
- –Lighting
- –Process heating

By confusing or mixing these concepts, economic tend to limit resource options and lock-in existing technology choices

Representing Energy Services

- Requires a fundamental understanding of manufacturing processes and decisions not currently mapped into most models
- Focus on what is actually being decided upon and actually being done
- Understand how demand for service can actually be met:

Service Demands	Technology Choices
Refrigeration	Vapor compression, absorption
Fastening	Welding, bonding, mechanical
Process Heat	Steam, convection, IR, RF

Exergy Service Demands

- Energy and the quality of that energy are two entirely different attributes
- Ayres suggests using “exergy” service to reflect the “second law of thermodynamics” (including “quantity” and “quality” of the energy resource)
- Using higher quality than necessary is “inefficient”
- Allows tracking of embodied energy

Characterizing Delivered Exergy Services in Food Processing

Four Discrete Steps:

- Identify energy services
- Identify set of technologies that can satisfy service demands
- Identify energy resources that supply technologies
- Map resources to service demands

Start with NEMS representation

NEMS Representation of Food Energy Use

Figure 1. Industrial Model Components

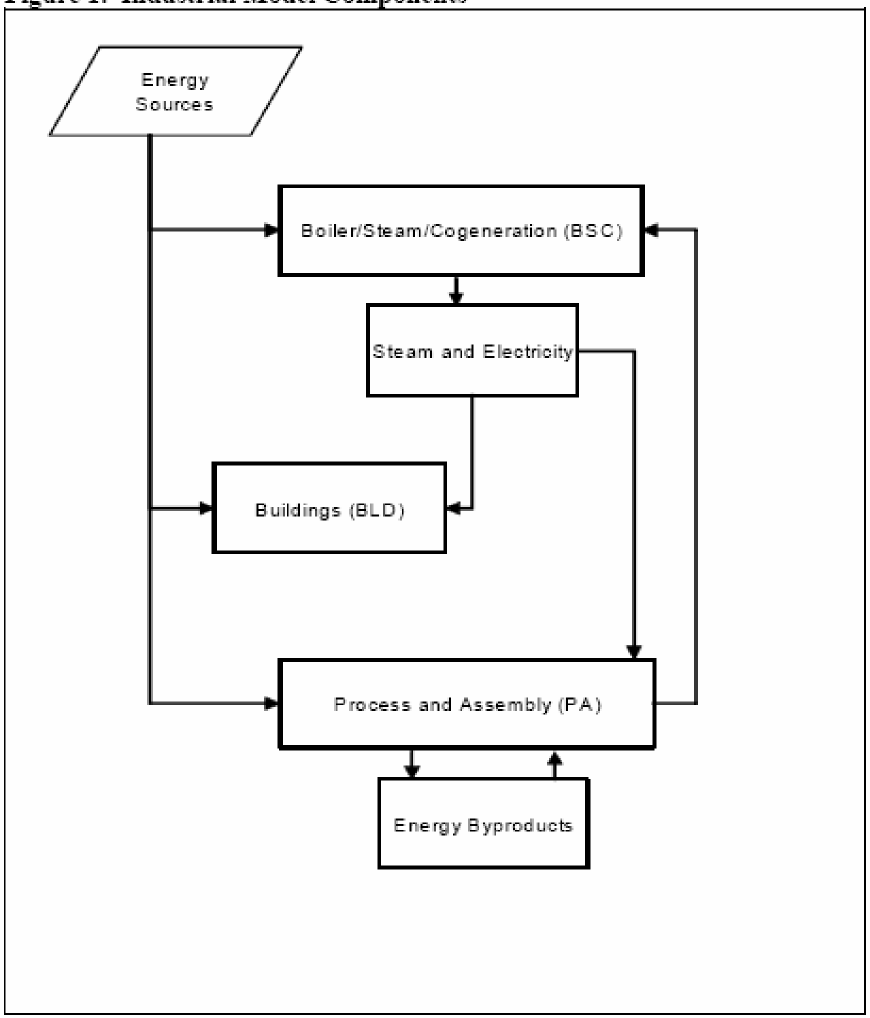
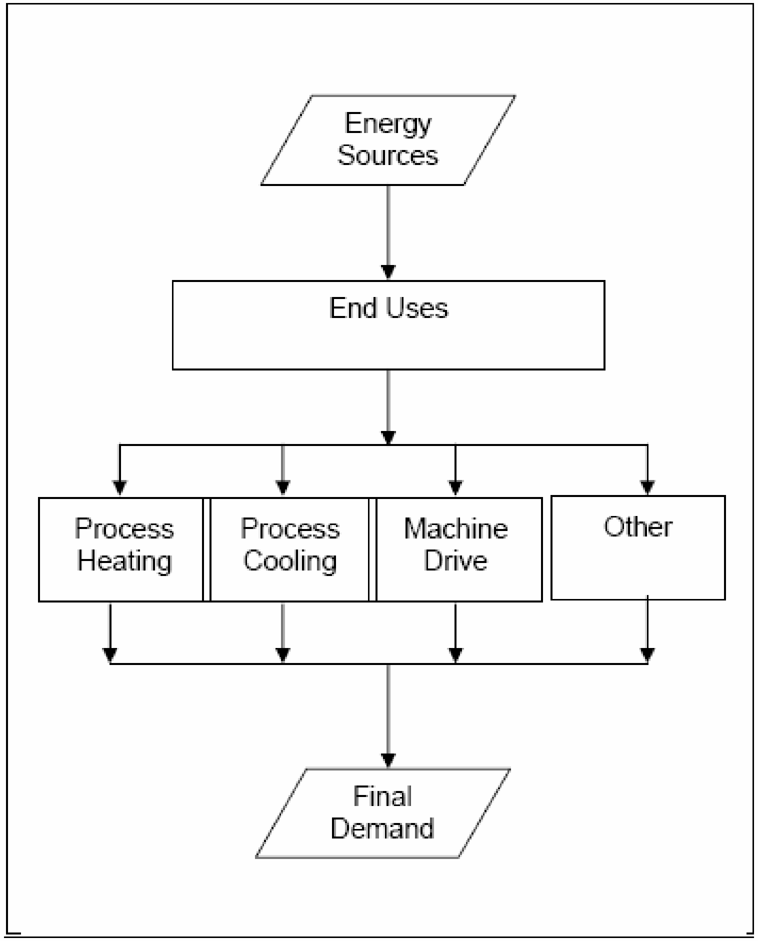


Figure 2. Food Industry End Uses



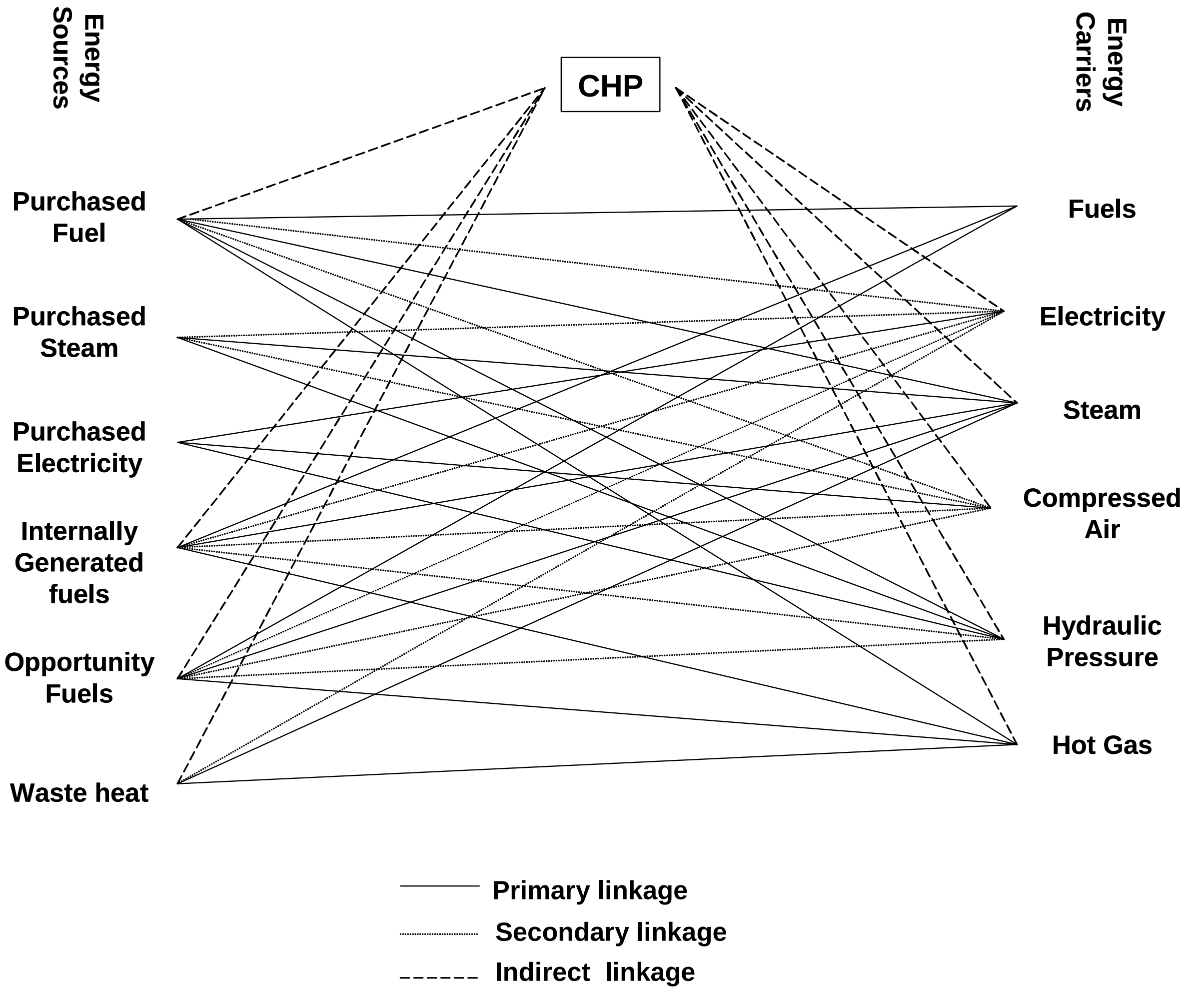
Proposed Approach

- Separate "energy resources" from "energy carriers" and "energy services"
- Create intermediate transformation for steam and electricity generation and CHP
- CHP could drive the future of steam
- Understand options for energy carriers to satisfy service demands
- Test with representation of Food Processing (NAICS 311)

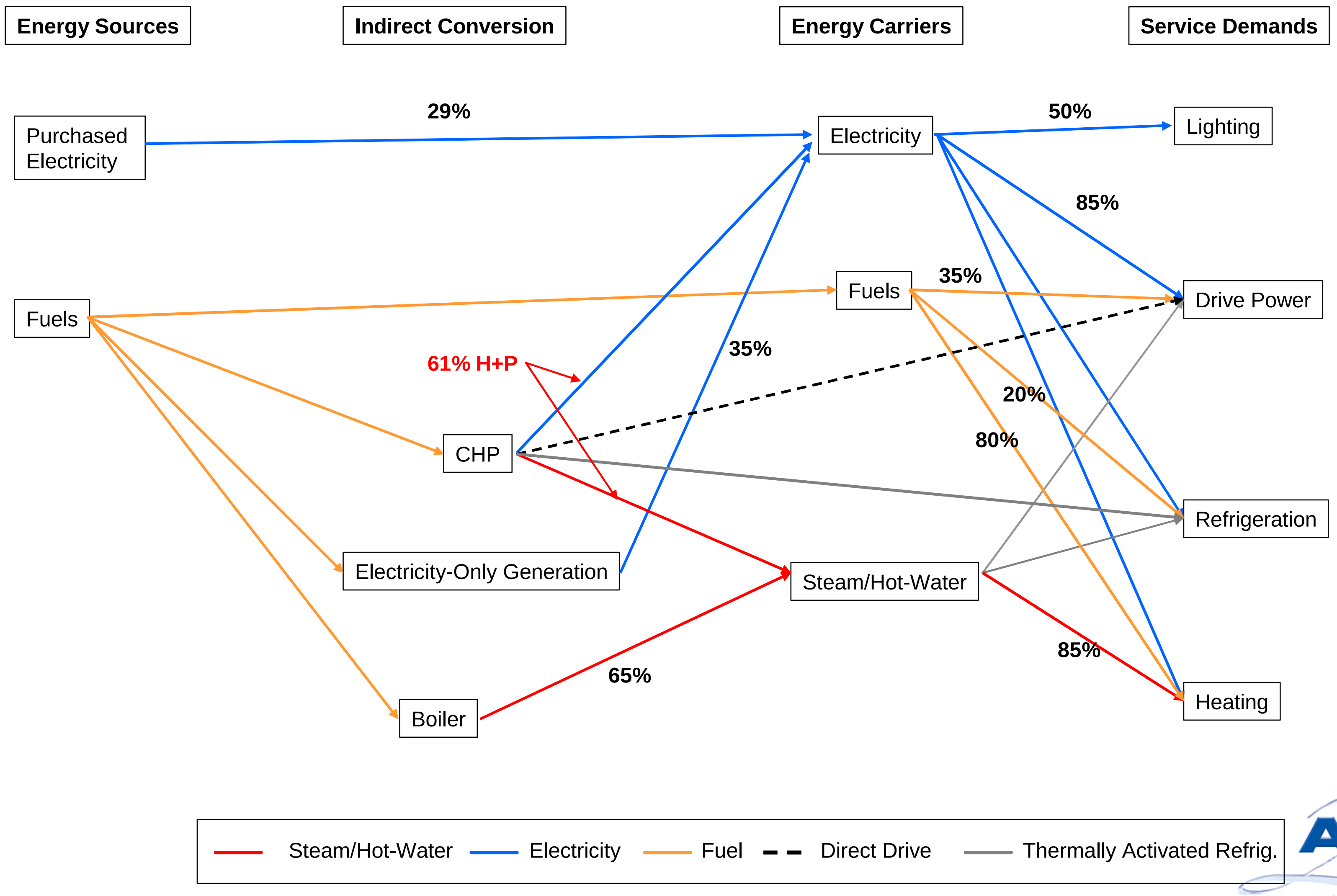
Food Products Exergy Service Demands

Service Demand	Exergy Service (Tbtu)	
Illumination	6.9	0.7%
Drive Power	131.5	13.6%
Refrigeration	165.9	17.1%
Heating	663.5	68.6%

Linking Energy Sources and Energy Carriers



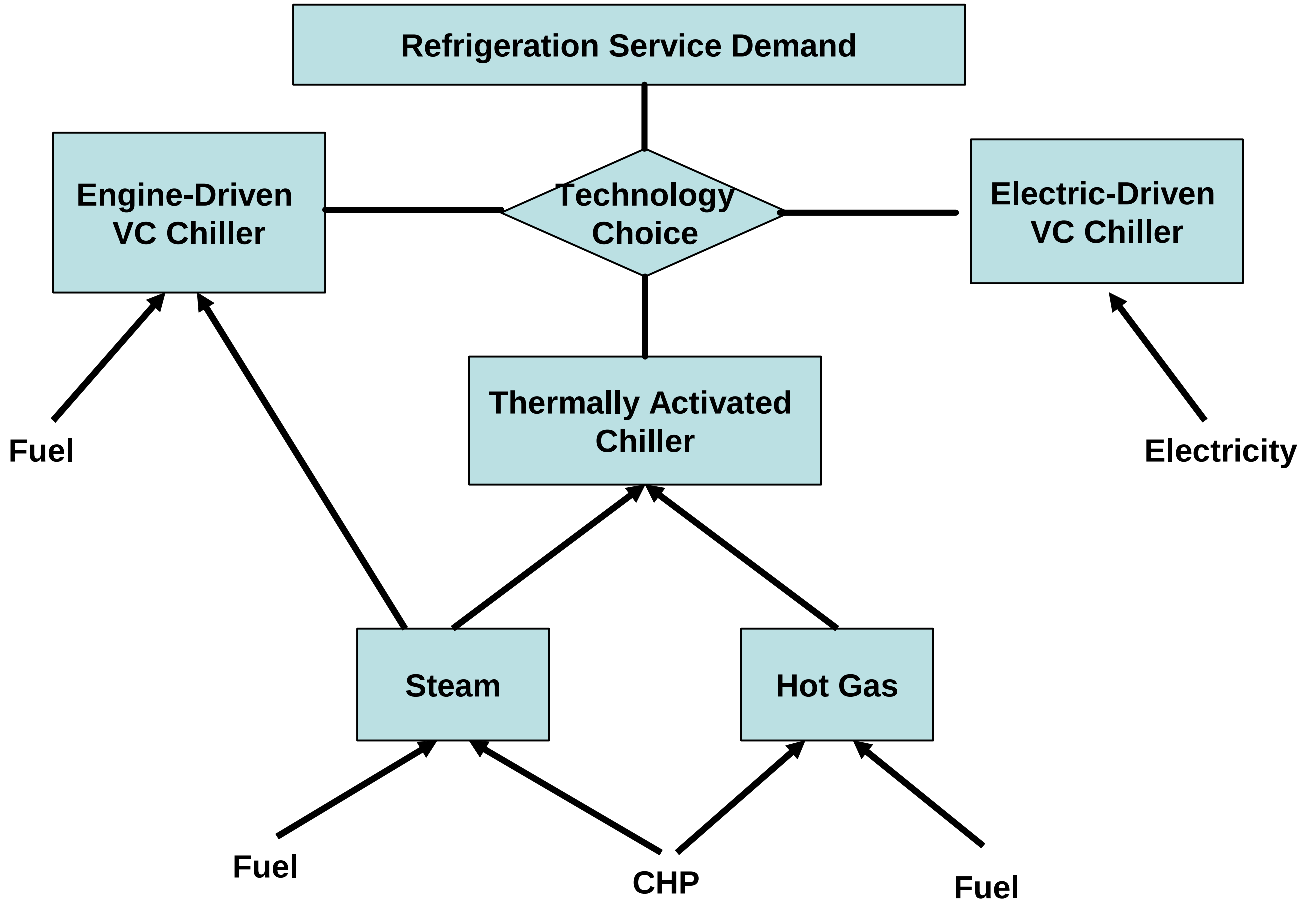
Mapping Energy Flows in Food



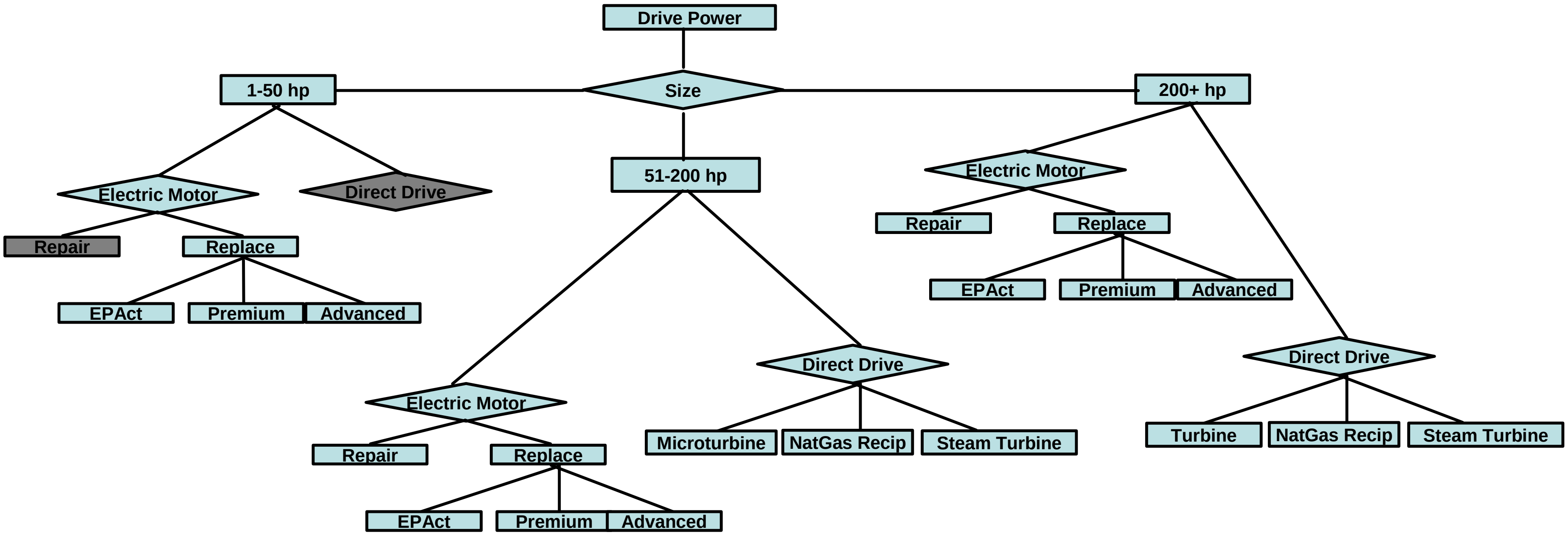
Representing Technology Choice

- Based on industrial decision tree
- Can be represented as constrained hierarchy of production functions
- Requires understanding of both the set of technologies and the required service demands (rather than assumed “energy flows”)
- Allows a greater variety of resources to compete to satisfy a service demand

Refrigeration Technology Choices



Drive Power Technology Choices

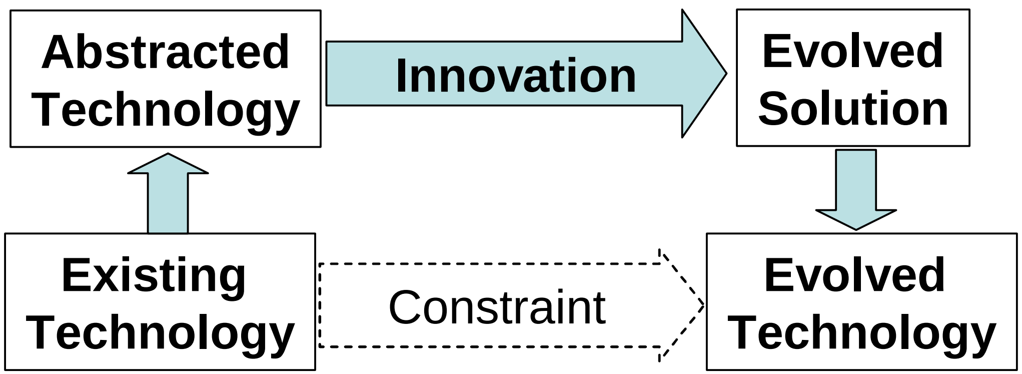


Implications of Alternative Energy Representation

- Allows exploration of a wider range of technology choices – Endogenous CHP and fuel switching representation
- Doesn’t lock in resource or technology choices
- Allows understanding of relative importance of service demands
- Highlights energy “constraints”

Understanding Technological Change

- Need to understand technology change
- Build on TRIZ – theory of directed innovation

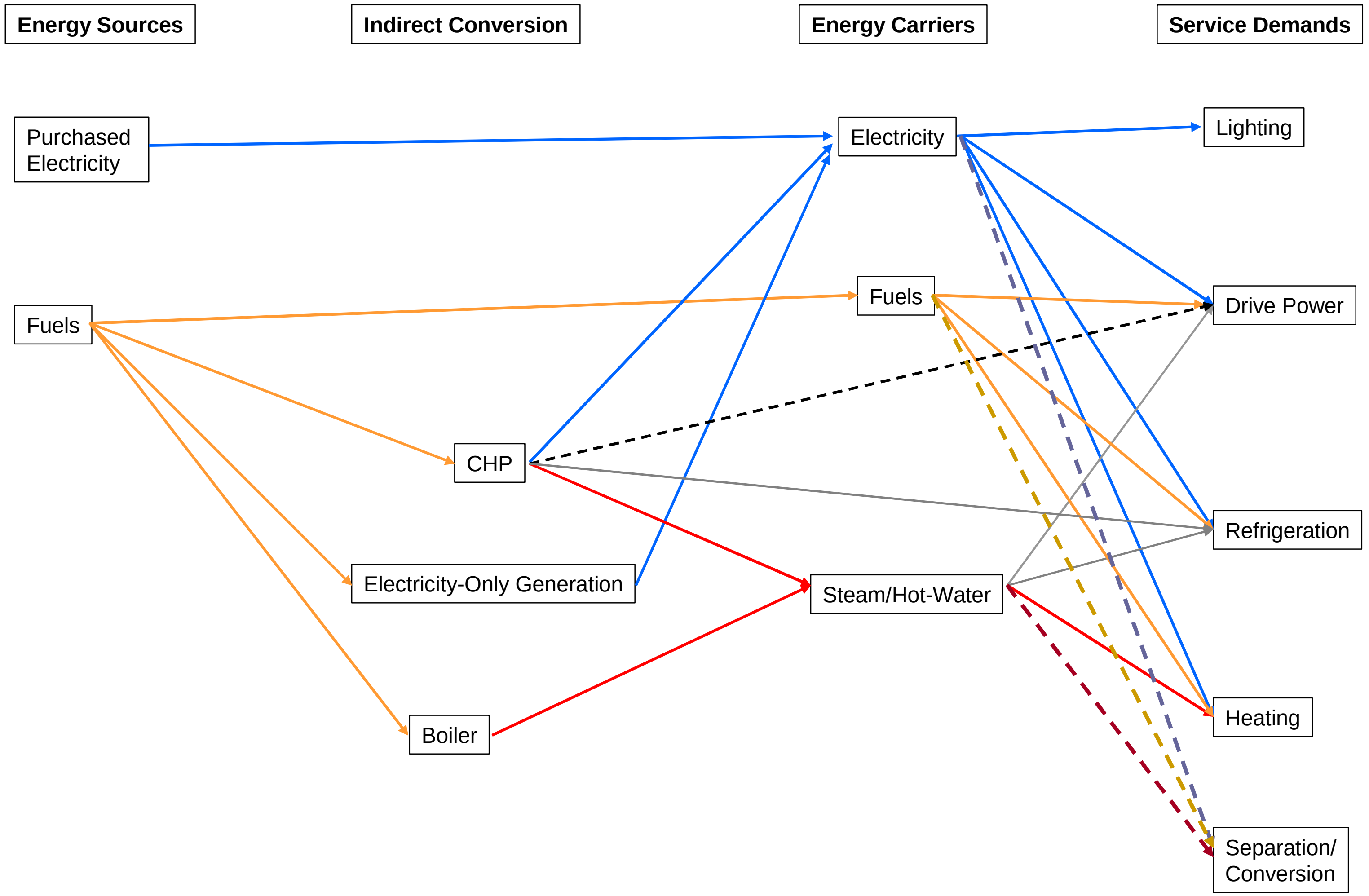


- Need to understand products change
- As a result service demands change

Example of Change in Service Demand

- Currently food products manufacturing processes raw food stuffs into final products
- Technologies emerging that can assemble products from building blocks
- Use simple amino-acids, fats, and simple sugars to “replicate” product using ink-jet like technology

Possible Structural Changes in Food Products Manufacturing



Conclusions and Need for Further Work

- Service demands can be defined from available data
- While “errors” likely no worse than rigidity of current representations
- Refine and complete technology characterizations
- Need to code into model – AMIGA
- Need to extend to other manufacturing sectors