NETPLAN Overview

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April 1, 2009 | Iowa State University
## Model Formulation

<table>
<thead>
<tr>
<th></th>
<th>Operation</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>Flows (MWh, MMBTu)</td>
<td>Capacity of power plants, transmission, pipelines…</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td>What mode/fleet does every ton transport?</td>
<td>Capacity of:</td>
</tr>
<tr>
<td>-Infrastructure</td>
<td></td>
<td>- Highway, rail…</td>
</tr>
<tr>
<td>-Mode</td>
<td></td>
<td>- Truck, train (electric, diesel, hybrid)</td>
</tr>
</tbody>
</table>
Model Formulation: Energy

- Network model
Model Formulation: Energy

- Links within a network: carriers
- Links between networks: conversion
Cost Minimization: Energy Formulation

\[
\begin{align*}
\min \{ & CostOp + CostInv \} \\
\text{subject to:} \\
\sum_k \eta_{(j,k,l)} f_{(j,k,l)}(t) - \sum_i f_{(i,j,l)}(t) = d_{(j,l)}(t) \\
\mathcal{Lb}_{(i,j,l)}(t) \leq & f_{(i,j,l)}(t) \leq \mathcal{Ub}_{(i,j,l)}(t) + \sum_{z=0}^{t} \mathcal{CapInv}_{(i,j,l)}(z) \\
\mathcal{LbInv}_{(i,j,l)}(t) \leq & \mathcal{CapInv}_{(i,j,l)}(t) \leq \mathcal{UbInv}_{(i,j,l)}(t)
\end{align*}
\]

where:
\[
\begin{align*}
CostOp &= \sum_t \sum_{(i,j,l)} (1+r)^{-t} \cdot costOp_{(i,j,l)}(t) \cdot f_{(i,j,l)}(t) \\
CostInv &= \sum_t \sum_{(i,j,l)} (1+r)^{-t} \cdot costInv_{(i,j,l)}(t) \cdot \mathcal{CapInv}_{(i,j,l)}(t) \\
d_{(j,\mathcal{Ren})}(t) &= \sum_t \mathcal{HeatRate}_{(i,j,l)}(t) \cdot f_{(i,j,l)}(t)
\end{align*}
\]

Decision Variables: \( f_{(i,j,l)}(t), \mathcal{CapInv}_{(i,j,l)}(t) \geq 0 \)
Model Formulation: Transportation

- For each link between two states:
  - Projection on the tons of each commodity are assumed to be known
  - The objective is to determine:
    - Infrastructure used
    - Type of fleet used
    - e.g. Highway and truck
  - We don’t determine the route, we find the mode
Model Formulation: Transportation

Node A

Railway
- Diesel Train
- Hybrid Train

Highway
- Diesel Truck
- Ethanol Truck
- Hybrid Truck

River
- Barge

Node B

Node B

Transportation network diagram with nodes and transportation modes.
Cost Minimization: Transportation Formulation

\[
\begin{align*}
\text{min} \{CostOp + CostInv\} \\
\text{subject to :} \\
\sum_m f_{(i,j,k,m)}(t) &= d_{(i,j)}(t) \\
\sum_k f_{(i,j,k,m)}(t) &\leq \text{fleet}_{ub_{(i,j,m)}}(t) + \sum_{z=0}^{i} \text{FleetInv}_{(i,j,m)}(z) \\
\text{lbFleetInv}_{(i,j,m)}(t) &\leq \text{FleetInv}_{(i,j,m)}(t) \leq \text{FleetInv}_{(i,j,m)}(t) \\
\sum_k \sum_{m \in I} f_{(i,j,k,m)}(t) &\leq \text{Inf}_{(i,j,I)}(t) + \sum_{z=0}^{i} \text{InfInv}_{(i,j,I)}(z) \\
\text{lbInfInv}_{(i,j,I)}(t) &\leq \text{InfInv}_{(i,j,I)}(t) \leq \text{ubInfInv}_{(i,j,I)}(t)
\end{align*}
\]

where:

\[
\begin{align*}
CostOp &= \sum_t \sum_{(i,j,l,m)} (1+r)^{-t} \text{costOp}_{(i,j,l,m)}(t) f_{(i,j,l,m)}(t) \\
CostInv &= \sum_t \sum_{(i,j,m)} (1+r)^{-t} \text{cFleetInv}_{(i,j,m)}(t) \text{FleetInv}_{(i,j,m)}(t) \\
&\quad + \sum_t \sum_{(i,j,l)} (1+r)^{-t} \text{cInfInv}_{(i,j,l)}(t) \text{InfInv}_{(i,j,l)}(t) + \\
d_{(j,Fjolv)}(t) &= \sum_{l,m} \text{fuelCons}_{(i,j,l,m)}(t) f_{(i,j,l,m)}(t)
\end{align*}
\]

Dec. Variables: \( f_{(i,j,l,m)}(t), \text{FleetInv}_{(i,j,m)}(t), \text{InfInv}_{(i,j,I)}(t) \geq 0 \)
Proposed Multiobjective Solver

Multiobjective algorithm
Select front of solutions
Generate new generation

Cost Minimization

Sustainability Metrics
Resiliency Metrics

Investment Portfolio

Search and selection
Evaluation (fitness functions)
V1 Structure

Input data

Preprocessor

Parameters

NSGA-II Optimizer
Minimum Investment Enforced

MPS file

Minimum Cost Optimizer

Results
Desired Output INFORMATION

[Graphs and maps illustrating energy and transportation sustainability, cost, and resiliency]
All regions can invest on PC, IGCC, wind, solar

Conversion technologies assigned cost, efficiency, capacity, emission rate, investment data

Arcs represent electric transmission and rail (coal)

Demand must be satisfied, as well as peak demand
Solution example

Average generation (GW) per year
Emission index

- **Best Cost**
- **Index = 1**
- Proportional to demand
- **Best Sust.**
- **Index = 0**
- Proposed federal bills
Solution Space and Pareto front

The graphs show the solution space and Pareto front for a set of parameters, with the axes representing Total cost (Trillion $) and Sustainability Index. The scatter plots illustrate the distribution of solutions across different combinations of these parameters.