Forum on the Future of
Interactive Multiobjective Optimization

Hybridizing Interactive Multiobjective Methods

Past Experiences and Future Trends

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Outline

1. Motivation
   - Interactive Techniques
   - How to choose an Interactive Method
2. Two Real Applications
   - Determination of Electricity Mix in Andalucía
   - Optimal Size of a Solar Thermal Plant
3. Conclusions and Future Trends

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It is a resolution method for Multiobjective problems, where the information exchange between the decision maker and the analyst is carried out in a continuous way during the resolution process. The method progressively incorporates the information given by the Decision Maker so as to lead him to his most preferred solution.
Interactive techniques are specially suitable for favoring learning processes for both the decision maker and the analyst.

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- Learning phase.
- Decision phase.

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Basic Scheme of Interactive Methods

Steps of an Interactive Method

1. Generate initial efficient solution(s)
2. Present the current solution(s) to the DM
3. Is the DM satisfied with some solution?
   - ✓ If "Yes", then end.
   - ✓ If "No", go to step 4
4. Ask the DM for preferential information
5. Generate new efficient solution(s)
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What Type of Information may be Asked to the DM?

Types of Interactive Methods according to the information required

- Comparison Methods
  - ✓ Pair-wise comparisons
  - ✓ Several objective vectors
- Trade-off or local weights methods
  - ✓ The DM evaluates objective tradeoffs
  - ✓ The DM estimates subjective tradeoffs
- Level specification methods
  - ✓ Interactive Goal Programming methods
  - ✓ Reference Point based Methods
- Classification methods
- Non trading-off methods

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How do Interactive Methods Calculate New Solutions?

Types of Interactive Methods according to the optimization procedure

- Reduction of the feasible region
- Reduction of the weights space
- Feasible direction, line search
- Cutting planes (tradeoffs)
- Lagrange multipliers (constraint problems)
- Achievement scalarizing functions
- Steps towards the efficient frontier

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Desirable Properties (Afsar et al., 2021)

Topics

- Easiness to use.
- Cognitive burden.
- Sense of being in control.
- Ability to capture preferences.
- Learning about trade-offs.
- Satisfaction and confidence in the final solution.

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- Importance of assessing methods.
- Different methods may perform better at different stages.
- Choosing an interactive method is not trivial.

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Our Conclusion as Analysts

What do WE have to do?

- We have to choose a method:
  - ✓ For each problem
  - ✓ For each Decision Maker
- We need to offer a flexible framework:
- We will probably need to combine interaction styles.
  - ✓ Hybridize different interactive methods.
  - ✓ Application 1.
- We will probably need to combine solving techniques.
  - ✓ Hybridize interactive methods with EMO techniques.
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Main Features of the Study

Purpose

- Determine the most preferred electrical mix to cover the demand of Andalucía, taking into account economic, environmental and vulnerability criteria.
- Evaluate the cost of moving towards a more sustainable mix.
- DM: Regional Ministry of Environment of Andalucía.

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Elements of the Model

Variables

- 8 electricity generation systems: Lignite, Carbon, Oil, Natural Gas, Nuclear, Photovoltaic, Eolic, Hydraulic.

$$Y_j\text{: Installed capacity (GW) for system } j$$

- Demand: 108 time periods (t_k, hours), with a given hourly demand (d_k, GW).

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Elements of the Model (Cont.)

Constraints

- Diversification & security.
- Satisfaction of the demand.
- Electricity permanent availability.
- Technical constraints.

Objectives

- Cost
  - ✓ Fixed annualized costs.
  - ✓ Variable (fuel) costs.
- Vulnerability (Percentage of Imported Fuel).
- Environmental Objectives.
  - ✓ 12 Impact Categories.
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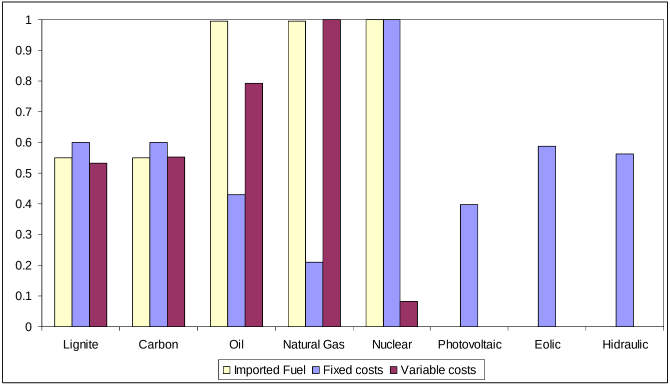
Cost and Vulnerability: Comparison of Alternatives



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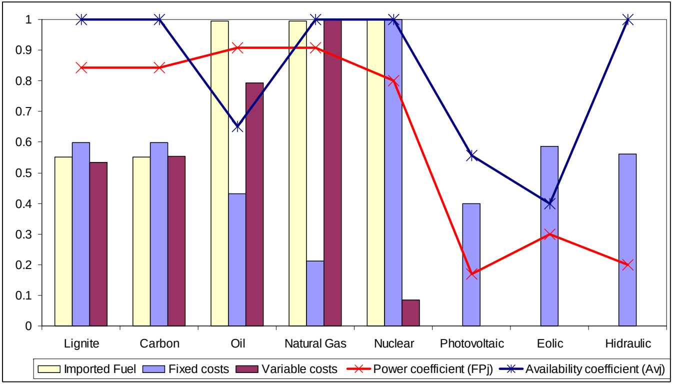

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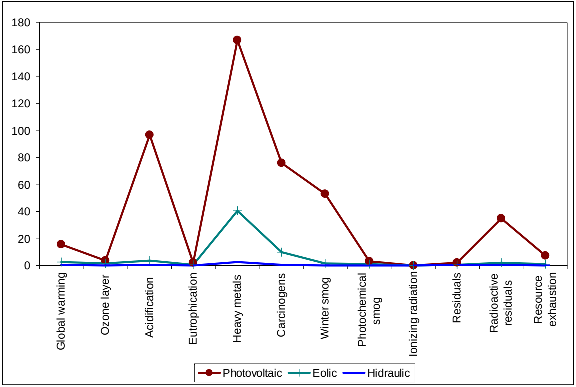

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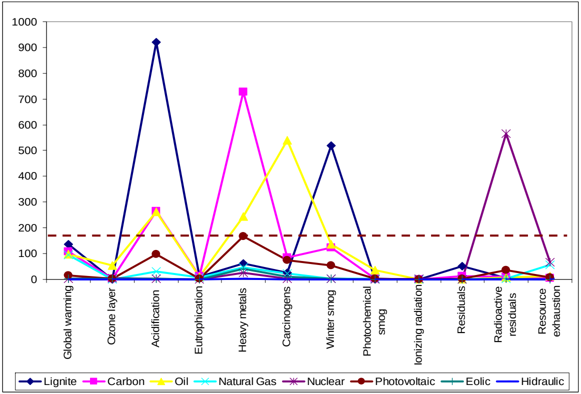

Model and Iterations

Features of the Linear Model

- 116 Variables.
- 1098 Constraints.
- 14 Objective Functions.

PROMOIN (Caballero, Luque, Molina, Ruiz, 2002). Iterations

- Initial Solution: minimum cost.
- Weighting of Objectives.
  - ✓ Cost – Vulnerability – Environmental
- Reference Points and Classification.
  - ✓ Improve Vulnerability
  - ✓ More balanced Environmental Impacts
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Results-Objectives

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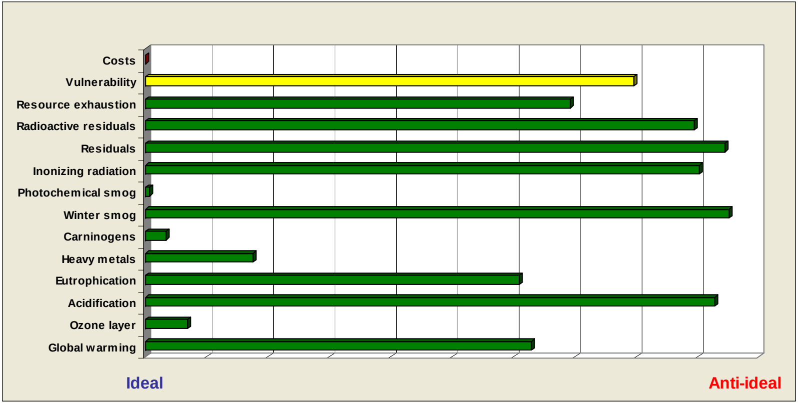
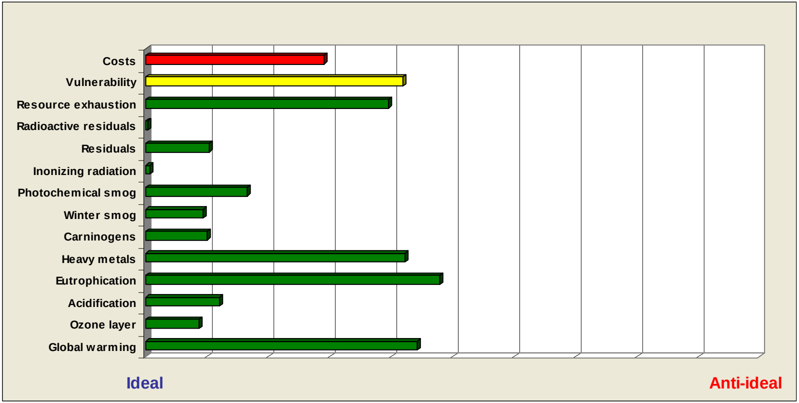


Results-Objectives

Weights



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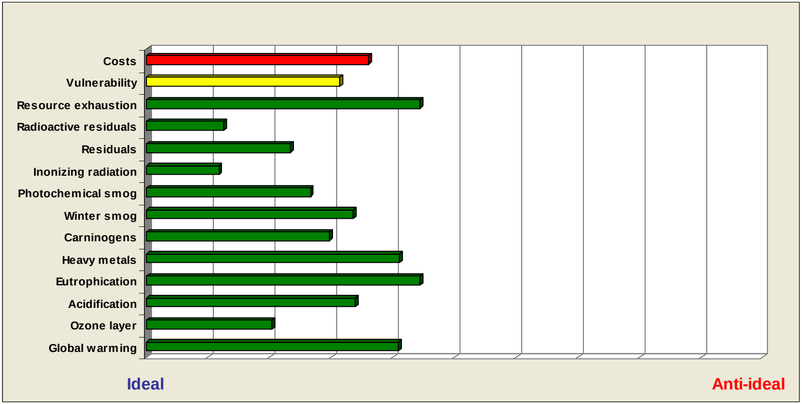
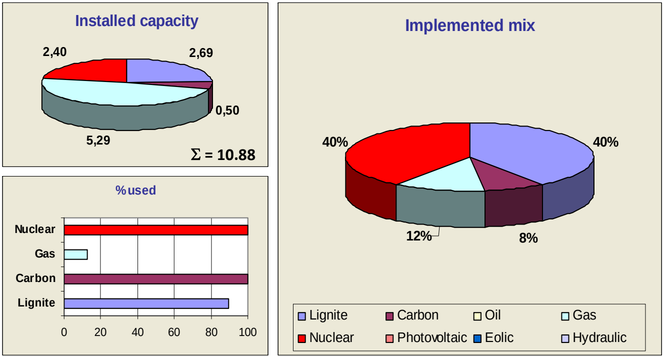
Reference Levels



Results-Variables

Minimum Cost



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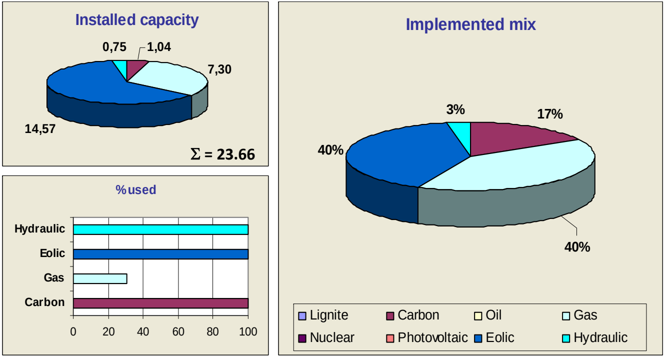

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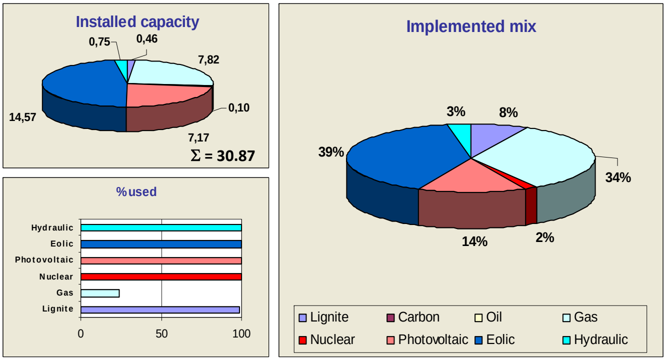
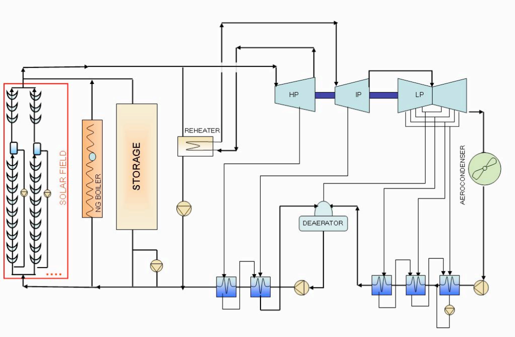


Purpose of the Study

Optimal Dimensions

- Solar Field
- Storage Tanks
- Auxiliary Boiler

Endesa Generación S.L.



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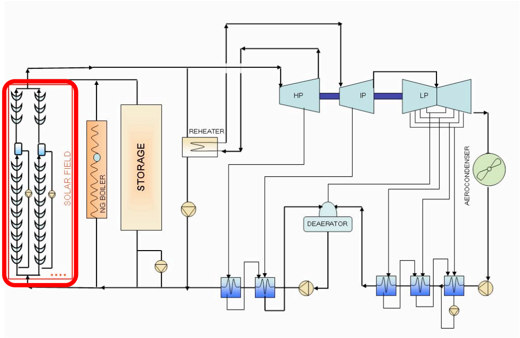

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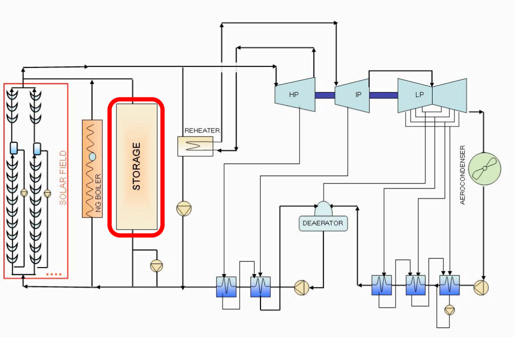

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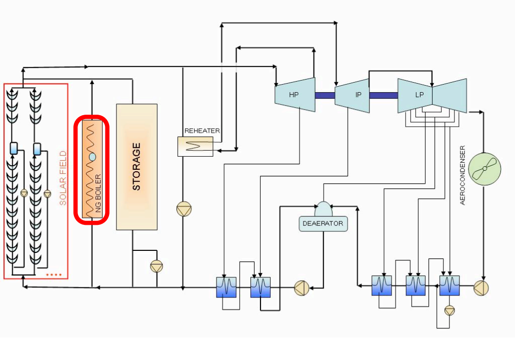

Elements of the Model

Variables

- A_C (m^2) Dimension of the Solar Field
  - ✓ File with expected direct solar radiation and temperature per hour (8760 hours) available. We determine the steam mass from the solar field at each hour.
  - ✓ $A_C \leq 750,000m^2$
- E (KJ) Capacity of Storage Tanks
  - ✓ One tank maximum capacity: 8 hours.
  - ✓ One tank fixed cost: 15 million €.
- P_{AUX} (KW) Power of the Auxiliary Boiler
  - ✓ Legal limit: 15% hybridization.
- L (%) Load Fraction Limit
  - ✓ $L \leq 75\%$.

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  - ✓ $A_C \leq 750,000m^2$
- E (KJ) Capacity of Storage Tanks
  - ✓ One tank maximum capacity: 8 hours.
  - ✓ One tank fixed cost: 15 million €.
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  - ✓ Legal limit: 15% hybridization.
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Why is the Problem so Complex?

Operation Strategy

Every hour, the following decisions are made:

1. If steam mass from the solar field is enough to work at L or more, work only with solar field.
   - ✓ If steam mass produces more than $L = 100\%$, store remaining steam.
2. If steam mass is not enough for L, and there is enough energy stored, complement to work at L.
   - ✓ Ambient losses in the tanks are taken into account.
3. If steam mass and storage are not enough for L, test hybridization condition.
   - ✓ If it is possible to hybridize with the auxiliary boiler, work at L.
   - ✓ If not, store steam mass from the solar field and stop plant.
   - ✓ After a 8 or more hours stop, the electricity produced is devoted to re-starting the system.

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- Hybridize with meta-heuristic techniques.

Yearly Profit

- Incomes.
  - ✓ 8760 hourly incomes.
  - ✓ Based on $FUNC_i$.
  - ✓ Taking stops into account.
  - ✓ Fixed selling price.
- Fixed costs.
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(Deb, Tewari, `http://www.iitk.ac.in/kangal/soft.htm`)

GA Solution

- Variables.
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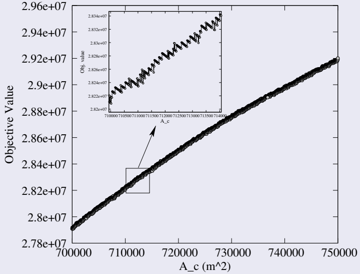
Optimal profit vs. A_C



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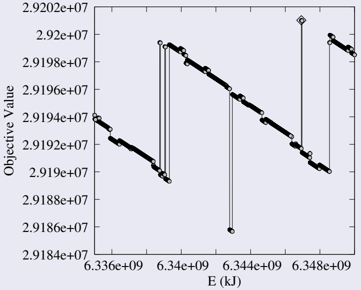

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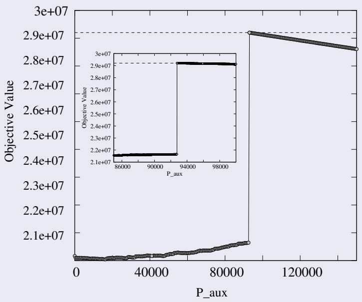

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The Multiobjective Model

Objectives

- Maximize Profit.
- Minimize Investment.
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Resolution Process

- Individual optima (GA).
- Efficient Front: NSGA-II (Deb et al, 2002).
- Reference Point based NSGA-II (Deb et al, 2006).
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Individual Optima

What we learnt

- Optimal investment cost.
  - ✓ No activity.
  - ✓ The cost of the tanks is the highest component.
  - ✓ Lower values of L are better.
- Optimal IRR.
  - ✓ Maximum of 16.16%, with $E = 0$ and $L = 25$.
  - ✓ For non-zero values of E, maximum IRR is around 14.84%.
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  - ✓ Small A_C and small L.
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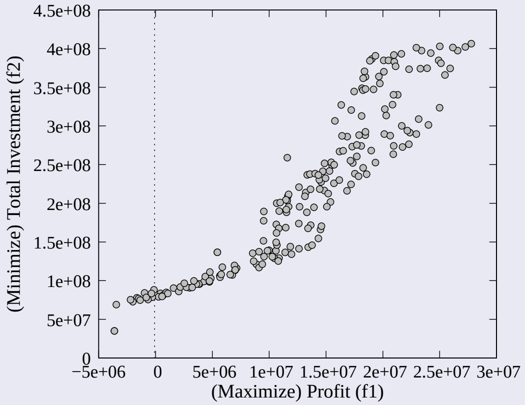
Profit vs. Investment Cost



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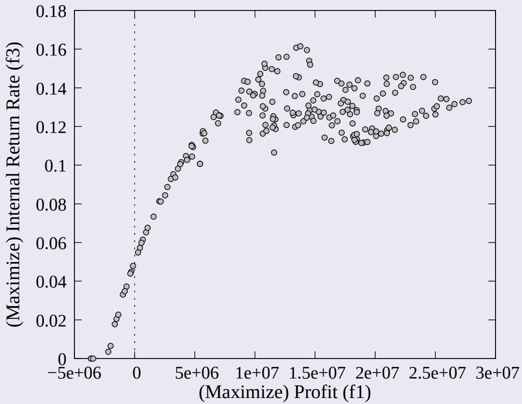

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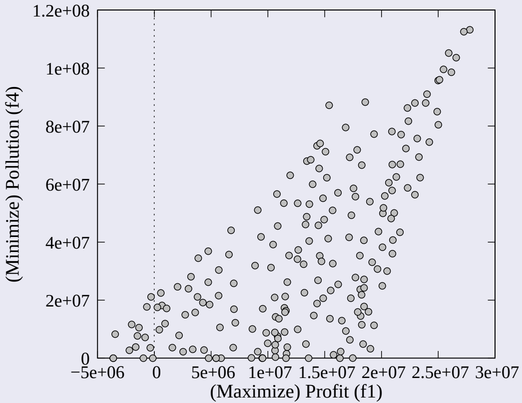


Final Approach: Reference Point Based NSGA-II + GA

Initial Variables

- $A_C = 750,000$
- $E = 15.68$ hours (2 tanks)
- $P_{AUX} = 92,768$
- $L = 75.00$

Final Variables

- $A_C = 490,312$
- $E = 6,39$ hours (1 tank)
- $P_{AUX} = 90,261$
- $L = 63,52$

Decision Variables

Final Approach: Reference Point Based NSGA-II + GA

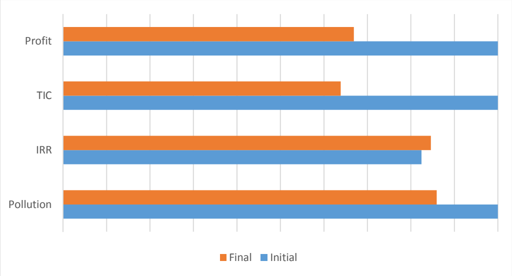
Initial Objectives

- Profit 29, 201, 020.
- TIC: 406, 769, 471.
- IRR: 13.32%.
- Pollution: 58, 125, 795.

Final Objectives

- Profit 18, 596, 015.
- TIC: 259, 779, 783.
- IRR: 13.67%.
- Pollution: 49, 956, 127.

Objective Functions



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3 Lessons Learned

- There is no such thing as “the best interactive method”
- Flexibility is extremely important
  - ✓ Importance of intuition.
  - ✓ Pay attention to “primary” responses or reactions of the DM.
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Interactive MOP as a Learning Process

We all Learn

- The modelling process itself is a rich learning phase for both the analyst and the DM.
- During the interactive learning phase, we learn:
  - ✓ About the structure of the feasible set.
  - ✓ About the tradeoffs among the objectives.
  - ✓ About the impact of the DM's preferences on the solutions obtained.
- It is only this learning process what makes the analyst and DM confident about the final solution obtained.

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Hybridizing different interactive methods

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  - ✓ Data analysis.
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And more future trends

...See the panel discussion tomorrow!

Thank you!

Thank you very much for your kind attention