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Comparison of Many-Objective Optimisation and Multi-Criteria Analysis for Improved Water-Energy Efficient Design of Water Treatment Works for India

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Projects Water4India & Saraswati are co-funded by the European Union within the 7th Framework Programme (FP7) and the Government of India

- Aims
- Study design
- Place and duration of the study
- Methodology
- Results
- Conclusions

Saraswati

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Aims

- To provide a user-friendly decision support tool
  - For selection of potable water treatment technology solutions
  - For selection of wastewater treatment technology solutions
  - Named: WETSUiT (WatEr Treatment decision SUpport software Tool)
- Challenges:
  - Water and energy efficient solutions in presence of many other conflicting criteria
  - Suitable for two **scales**: Centralised (treatment trains) and Decentralised (packages)
  - Existing **practice** and **constraints** need to be understood

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Aims

- What will the "WETSUiT" DSS tool provide?:
  - Built on considerable previous work on DSS tools for water treatment
  - Will improve decision making process for wastewater treatment:
    - Identify potential treatment solutions for user-defined **end-uses**:
      - e.g. cooling; irrigation (for different crops); groundwater recharge
    - Present the user with a number of near-optimal **solutions** – allowing them to negotiate the final **selection**
  - Similarly improve decision making process for potable water treatment taking into account nature of the raw source water / population size etc.

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Study design

- Stakeholder workshops
  - Requirements capture for the DSS tool (held May 2015)
- Design, Coding and Implementation of DSS tool
- Comparison of two approaches to optimisation
  - Multi-criteria analysis (MCA)
  - Many-objective optimisation (MOO)
  - Sensitivity analysis to study and compare the performance of MOO and MCA
- Pilot case studies in India

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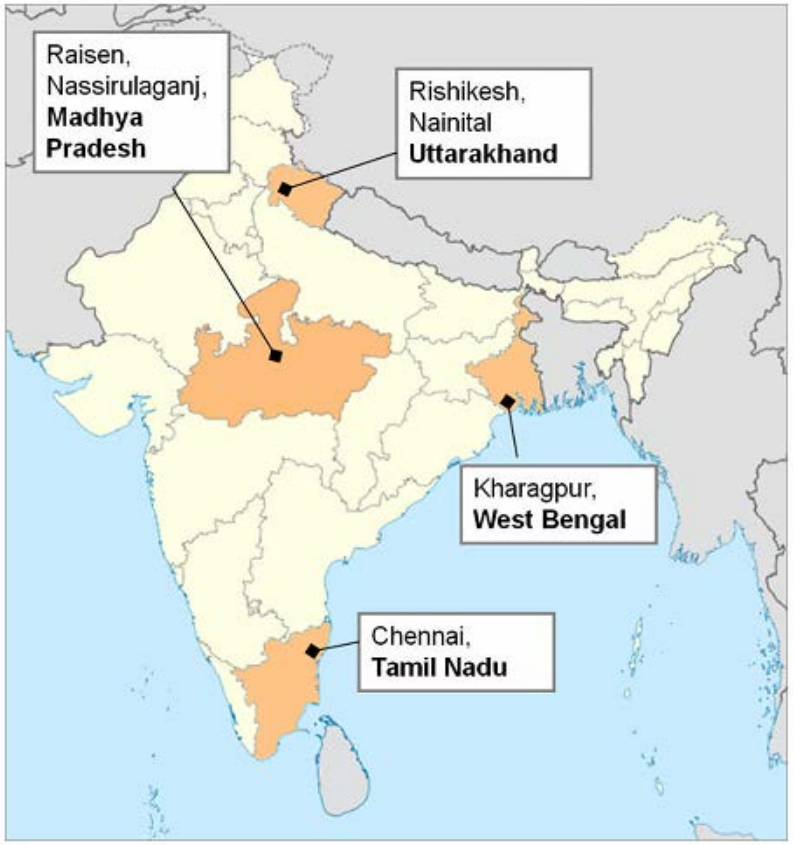
Place and duration of the study

- Water-challenged sites for pilot case studies in India (SARASWATI project)
  - Project 2013-16
  - Case studies 2015-16

Saraswati



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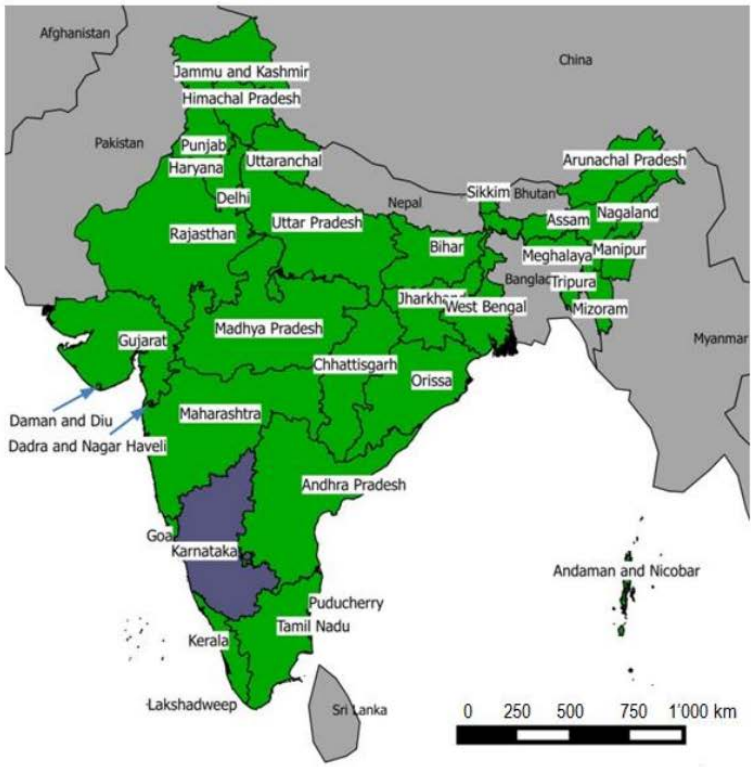
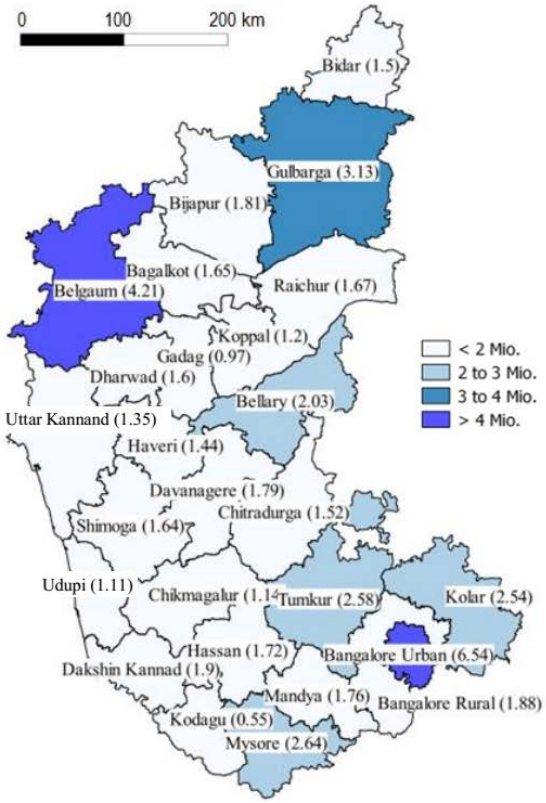
Place and duration of the study

- Karnataka
- Water4India
- 2013-16





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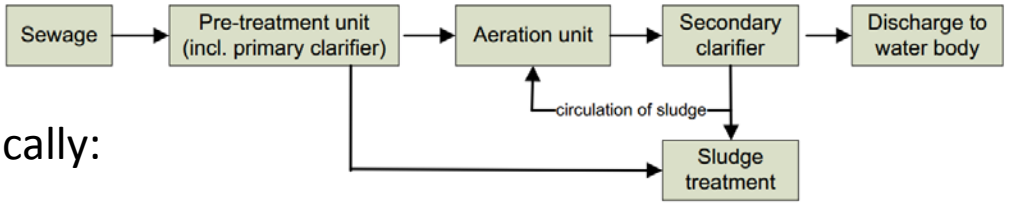
- Key DS tool components:



  - Rule-based **system model** automatically:
    - **selecting**, mixing and matching **technologies** in the treatment train
      - preliminary → primary → secondary → tertiary → disinfection
      - **using knowledge contained** within the DS tool about each process
    - keeping in view **influent characteristics** (flow, quality, pollutants etc)
    - taking into account intended **end use** of the effluent
    - allowing for user-defined **constraints/preferences**

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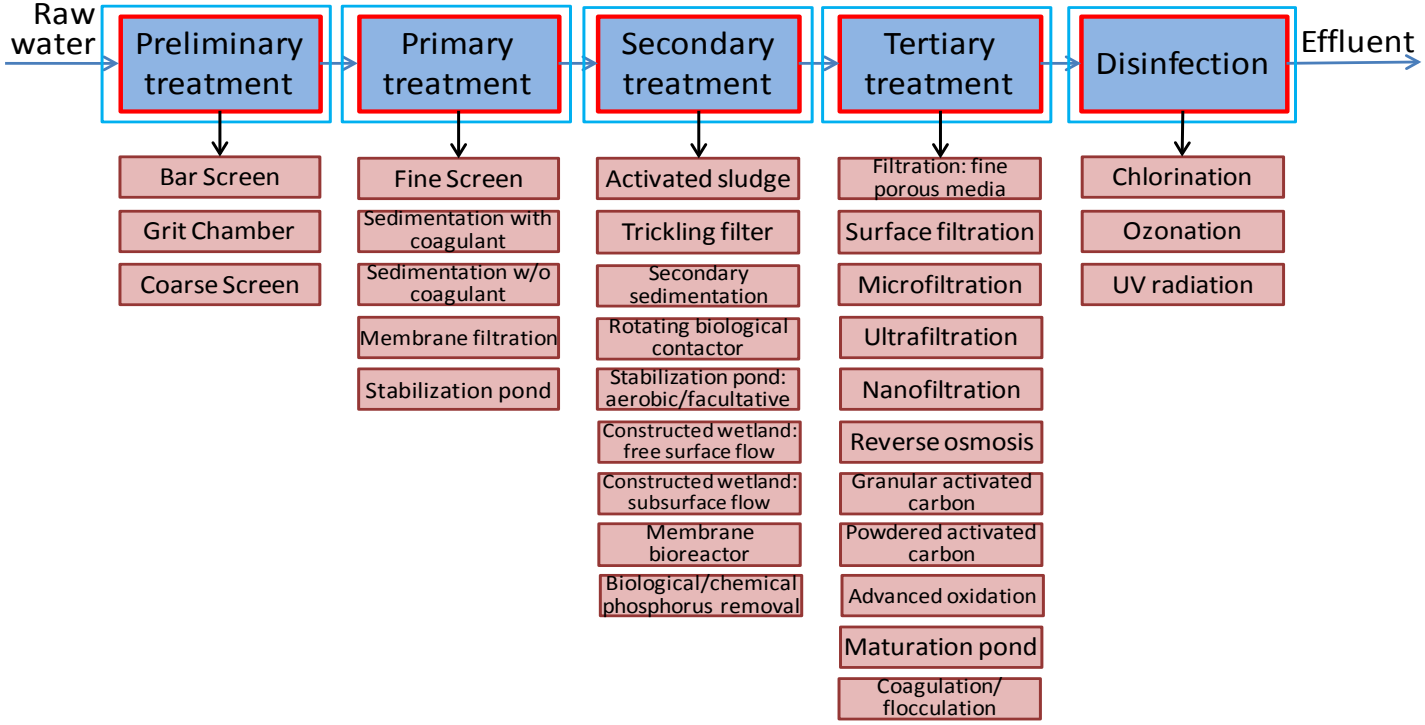
Methodology – technology choices

- Unit process choices at stages in wastewater treatment train:



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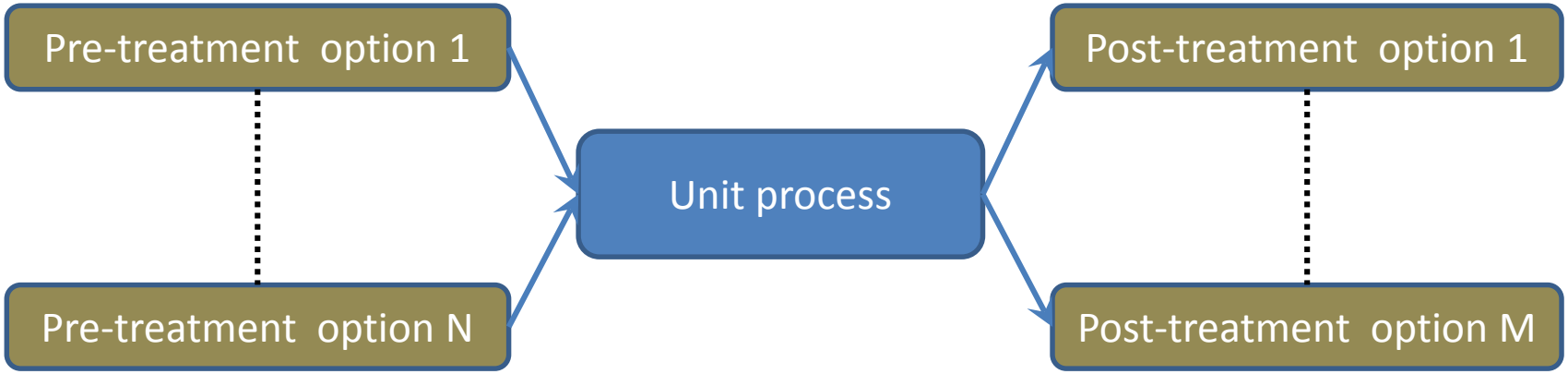
- Constraints for technology selection DS tool:
  - For each unit process there exists a set of valid pre-treatment process options
  - Same for post-treatment options



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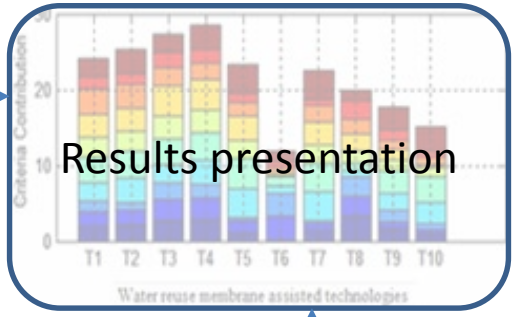
Methodology – WETSUiT Architecture

User-friendly Graphical User Interface (GUI)



Technology Library

Optimisation Engine

Decentralised Packages

Treatment Trains

Scenario Database

MCDA

MOO

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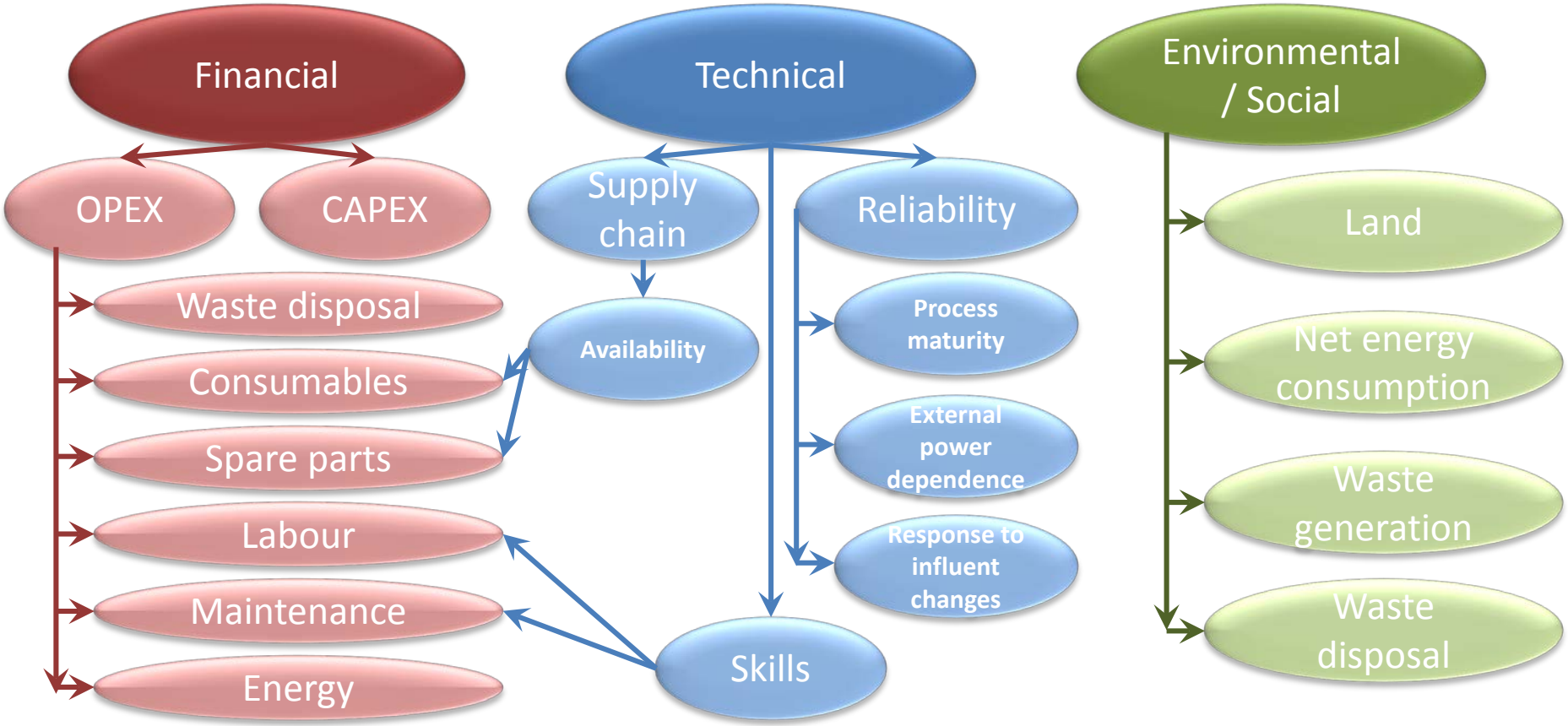
Methodology - Criteria



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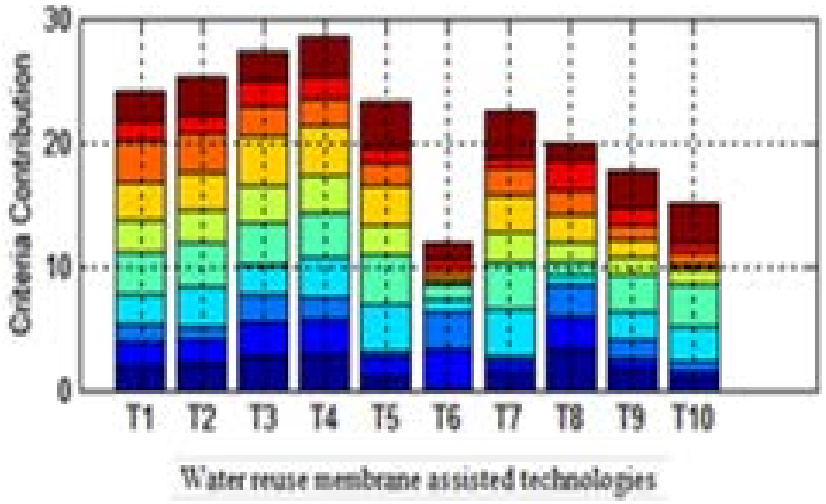
Methodology - MCA

- Multi-Criteria Analysis (MCA)
  - Pre-weighting of criteria against each other
    - based on stakeholder preferences
  - Single combined-objective algorithm
  - Criteria are additive



WatEfCon 2015
5-7 August 2015 Exeter, UK

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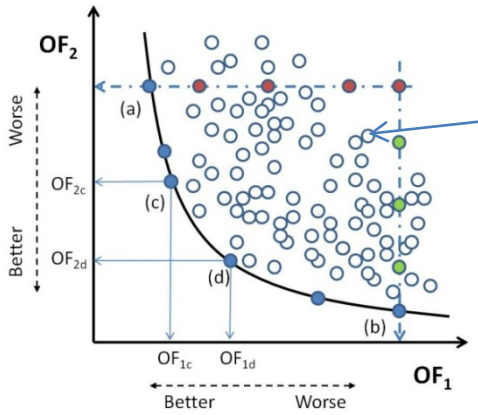
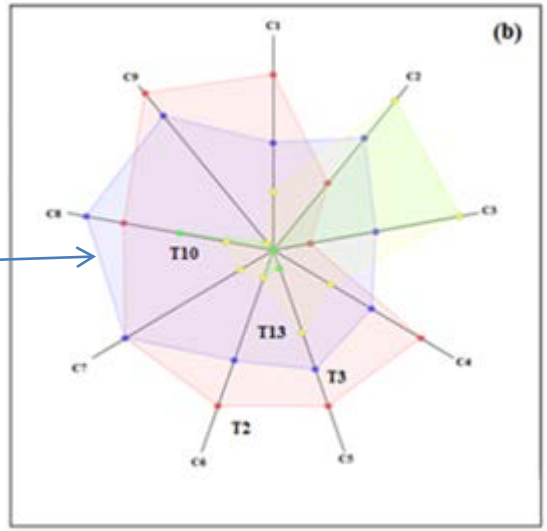
- Many-Objective Optimisation (MOO)
  - Treat each criterion as equally important
  - Many-objective algorithm (many dimensions)
  - Trade-off between criteria (indicators)



Technology

Star diagram



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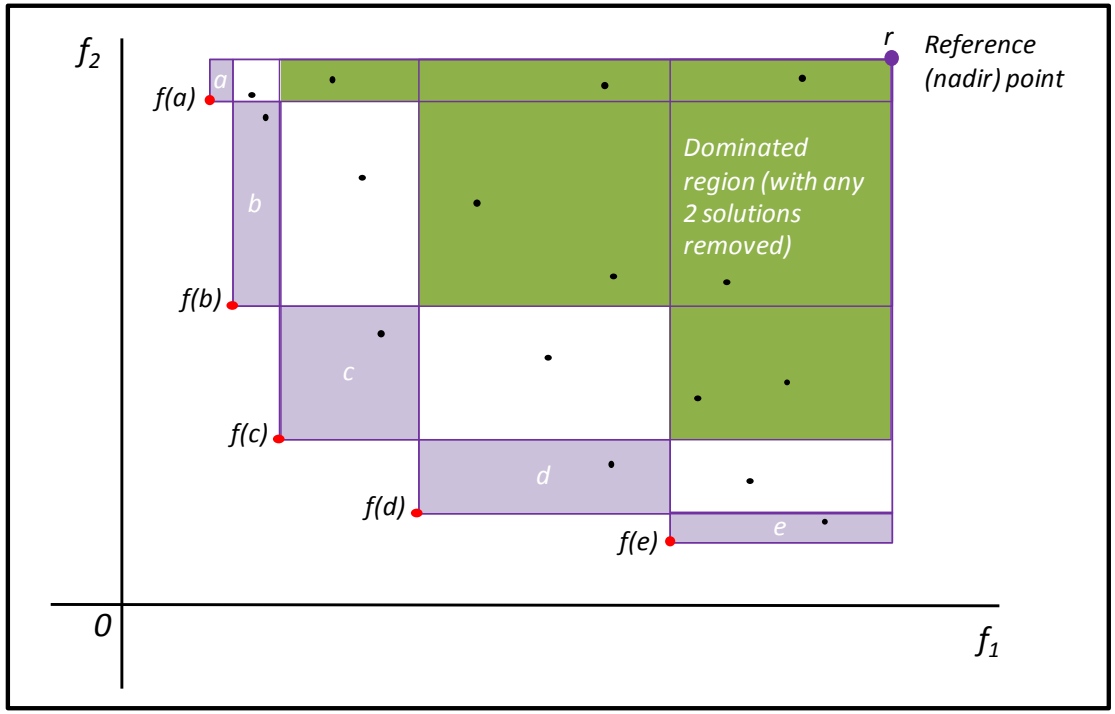
❑ Many-Objective Optimisation – HypE algorithm (2011)



2D example of solution fitness measured by hypervolume reduction method

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❑ Messages from Stakeholder Workshops

- ***Potential end users***
  - Housing colonies; Drainage boards; Engineers (e.g. from watchdogs; environmental regulators); Municipalities / Urban Local Bodies; Panchayats; Apartment complex managers; Construction industry (civil engineers / architects); O&M companies; NGO's; Consultants; Academic institutions.
- ***Proposals from stakeholders for improving uptake of the DSS tool***
  - The software needs to be freely downloadable
  - accessible in the long term (after the end of the project)
  - A programme of capacity building, awareness and user training as well as publicity and promotion is required.

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❑ Messages from Stakeholder Workshops

– ***Required / desired DSS software features***

- A clear-cut ranking of solutions is preferred in order to aid the final decision
- Social acceptability is an important group of criteria to include
- Should be flexible and adaptable to new technologies
- Needs to comply with water directives, standards and guidelines
- Users must be able to define local rates, technology preferences, budget etc.
- Should provide risk, uncertainty and sensitivity analyses
- Needs to operate for a range of scales of water treatment solution (decentralised / centralised)
- A 2-stage process should be adopted: 1) Constraints handling 2) Optimisation
- An alarm for inconsistent data should be provided.

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❑ Summary of WETSUiT Decision Support Tool

- Allows users to select / mix-and-match technologies for wastewater treatment solutions
- Contains information on decentralised packages and centralised unit-processes in technology library
- Employs a set of financial + technical + environmental + social criteria (user can select) to evaluate performance of the available options
- Optimiser rates feasible solutions and rejects non-feasible ones
- DS tool presents the list of nearest-optimal technology options with performances to user
- User selects which of these require full consideration for final wastewater treatment plant solution

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Questions?

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