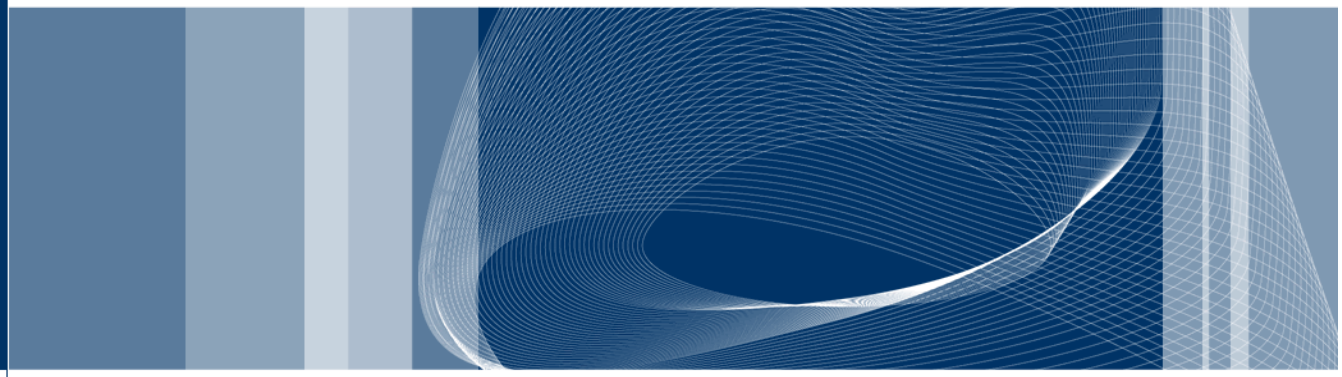
POLITECNICO DI MILANO

Knowledge
Aided
Engineering
Manufacturing
and
Related
Technologies



Systematic Innovation oriented at reducing energy and water consumption in household appliances

Niccolò Becattini

Gaetano Cascini - gaetano.cascini@polimi.it

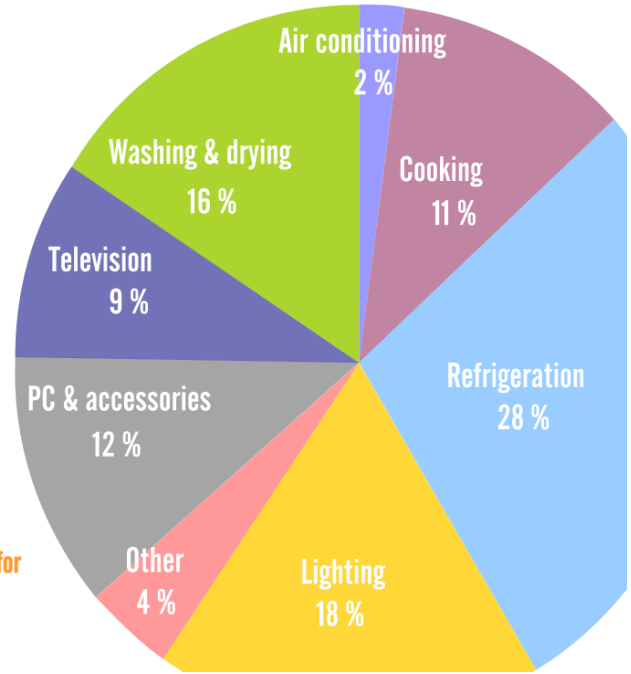
Walter D'Anna

Context

- The appliances in the kitchen are **low power devices**, however they are responsible for a **big amount of electrical energy consumption** in a country. A standard refrigerator consumes about 1 kWh per day. The household energy consumption per year is approximately 21% of the entire production (which is 70000 TWh); 28 per cent of this part is used for refrigeration purposes.

- Politecnico di Milano is involved in an ongoing project with Whirlpool aiming at the development of a "Green Kitchen", i.e. **a kitchen with drastically reduced consumption of energy (both electrical and thermal) and water**.

- **WARNING**: due to confidentiality issues it is not possible to show the most relevant solutions generated so far.

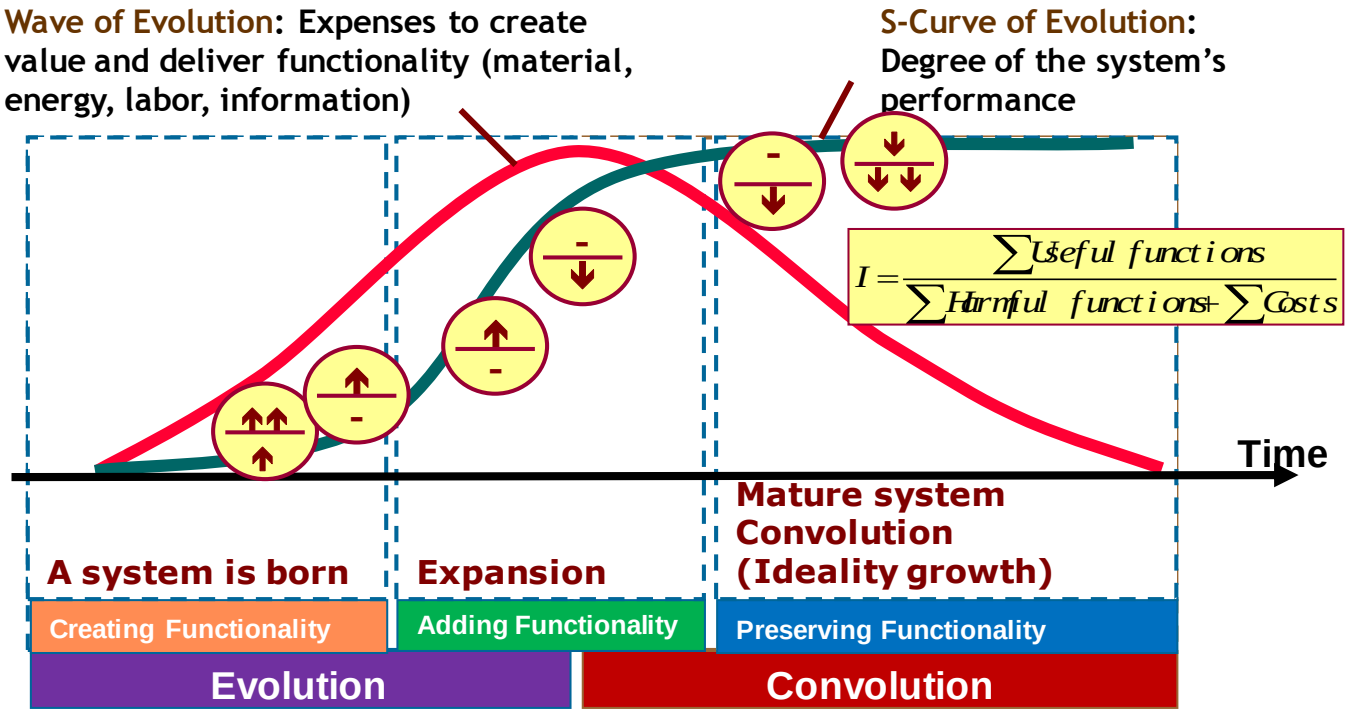


Distribution of Yearly Electricity Consumption for a Typical Household in Europe [Sintef]

Context

- The **reduction of resources consumption** is a typical goal for many innovation projects, and several attempts to face this challenge have been carried out by means of TRIZ.

- The evolution of a technical systems could be described through a S-Curve related to the increase of Ideality (4th Law of Systems Evolution). This increase is not proportional to the decrease of resources consumption.



Context and goal

- Besides, several publications like [1-4] provide just guidelines for driving development of products with criteria for eco-sustainability, **regardless of a global vision of the resources consumptions** and appropriate **criteria for defining priorities of intervention**.

[1] Russo D., Regazzoni D., Montecchi T.: "Eco-design with TRIZ Laws of Evolution", Proceedings of the TRIZ Future Conference 2009 – Timisoara (RO), November, 2009.

[2] Russo D., Regazzoni D.: "TRIZ Laws of evolution as eco-innovation method", Proceedings of IDMME - Virtual Concept 2008 Beijing, China, October 8 – 10, 2008.

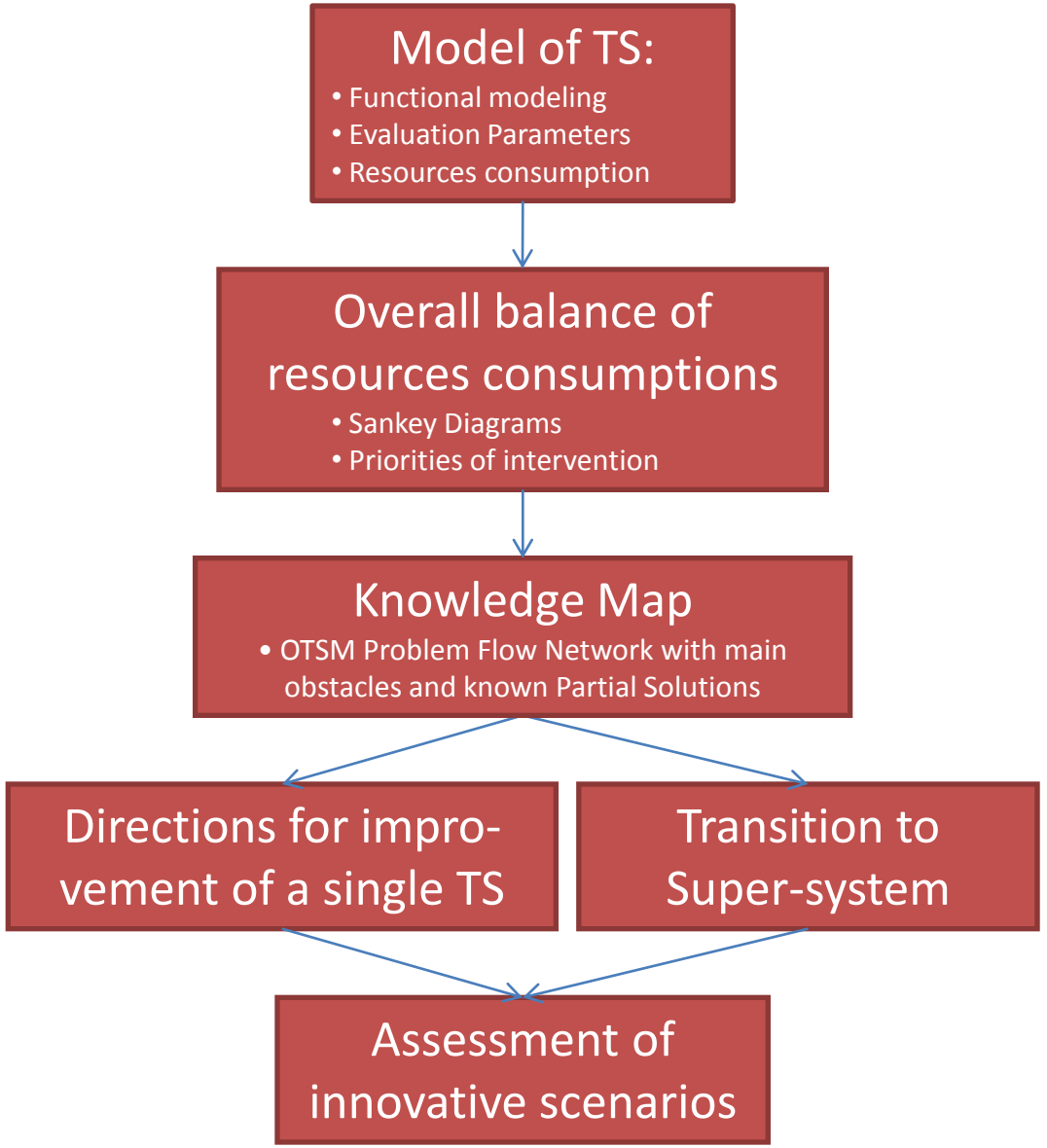
[3] Hideki Kobayashi: "A systematic approach to eco-innovative product design based on life cycle planning", Advanced Engineering Informatics, Volume 20, Issue 2, Engineering Informatics for Eco-Design, April 2006, Pages 113-125

[4] Hsiang-Tang Chang, "The Study of Integrating Su-Field Analysis Modeling with Eco-Innovative Concept for Product Design", International Symposium on Environmentally Conscious Design and Inverse Manufacturing, pp. 663-670, 2005 4th, 2005

- The goal of the present work is to define a roadmap for integrating TRIZ instruments and processes with global resources assessment tools

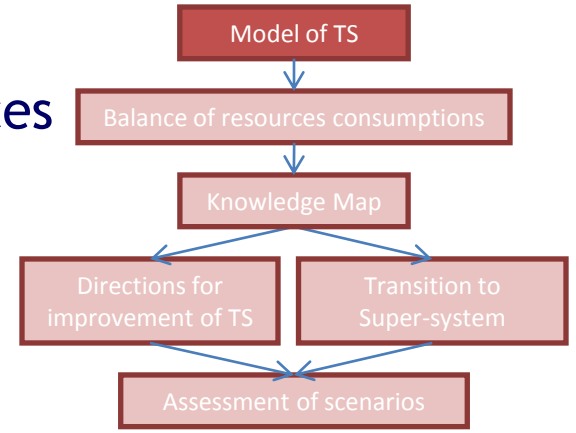
Outline and roadmap

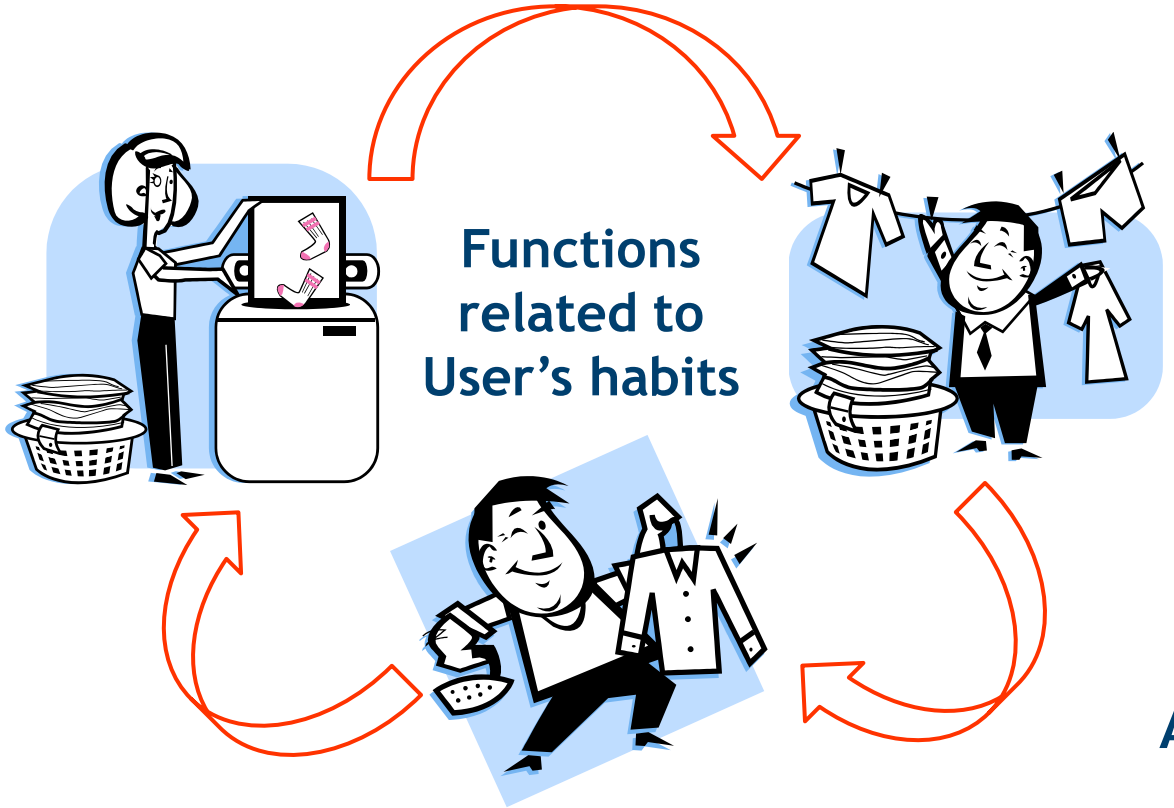
- Context and goal
- Overview of the proposed roadmap
- Detailed description of the steps and tools of the roadmap
- Exemplary (non confidential) results
- Conclusions

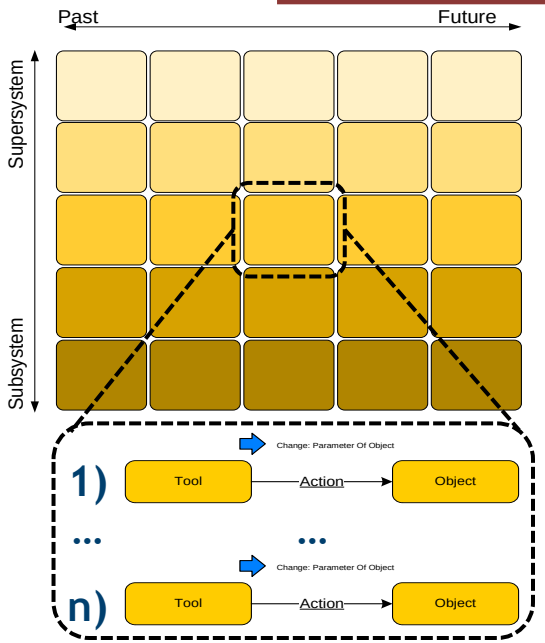


Model of the Technical System

- Model of the Technical System
  - List of functions currently delivered by the appliances and related technologies according to user habits.
  - Evaluation Parameters
  - Models of resources consumptions



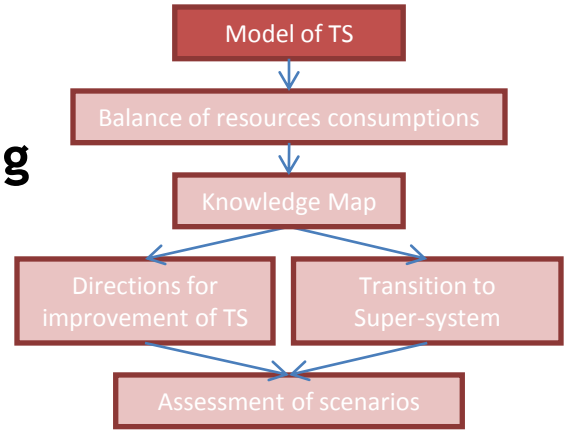


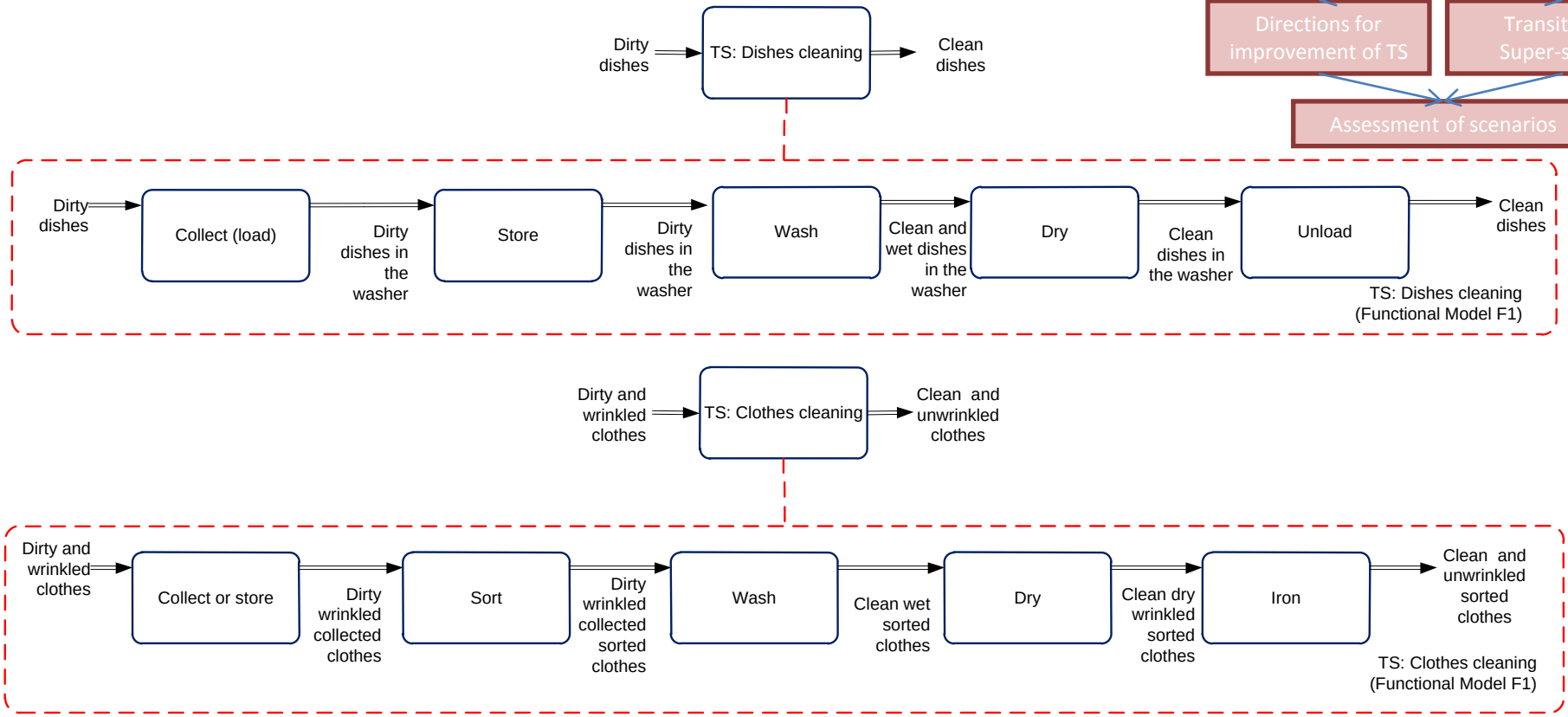


Available technologies for each resources consuming function

Functional Phases

- **The adopted model (NET) [5] is characterized by a fractal structure, such that it is possible to take into account an entire process without the need of modeling in details non-priority phases.**





[5] Cascini, G., Rotini, F., Russo D.: "Networks of trends: systematic development of system evolution scenarios", Proceedings of the 8th ETRIA TRIZ Future Conference, Twente, The Netherlands, 5-7 November 2008, ISBN 978-90-365-2749-1, pp. 31- 40.

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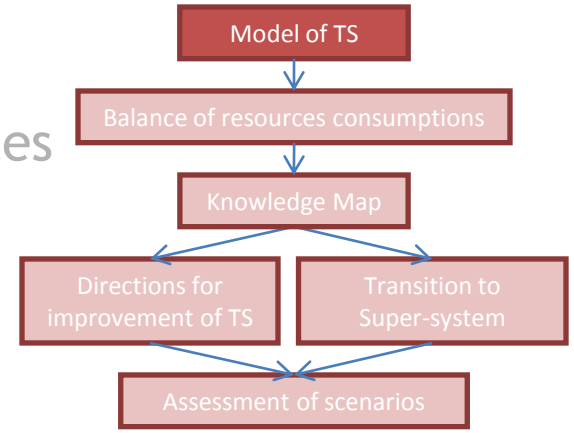
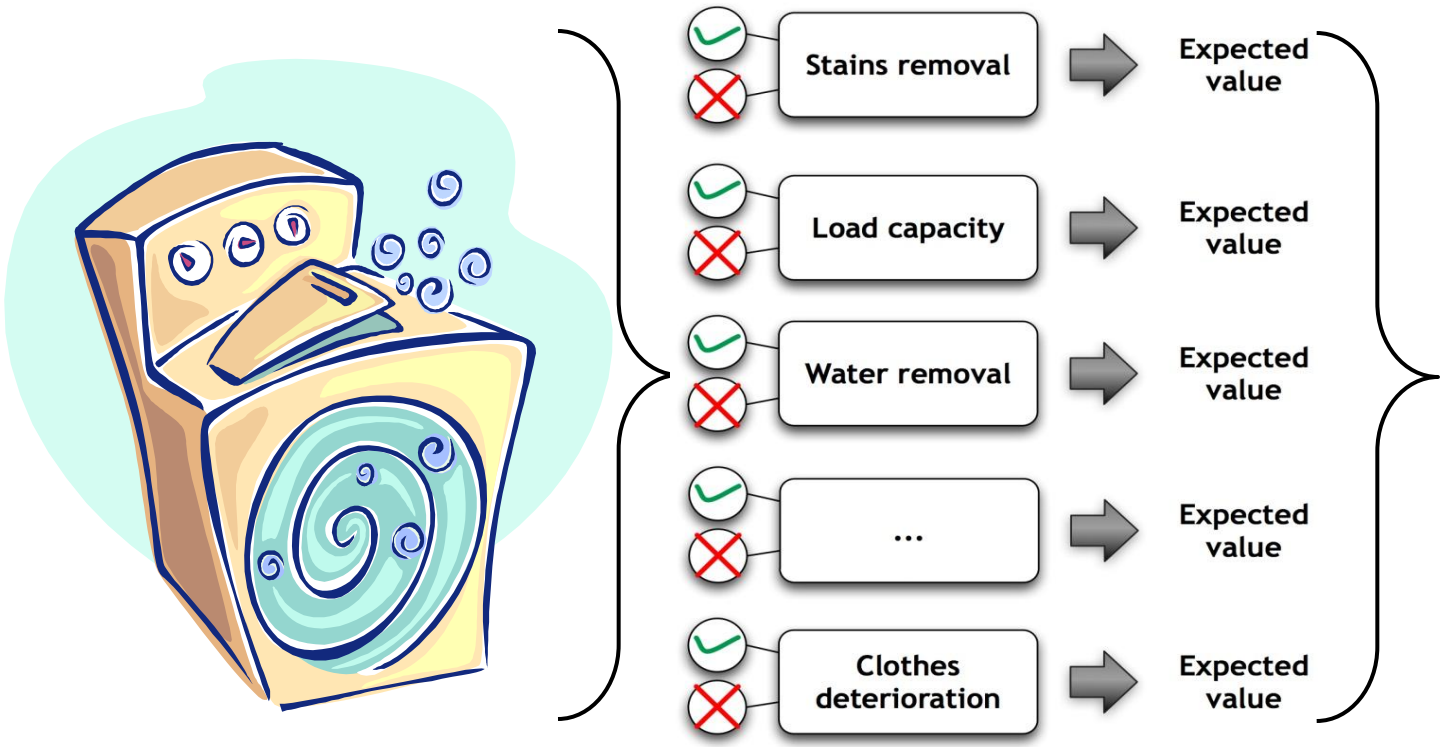




EP Ranking

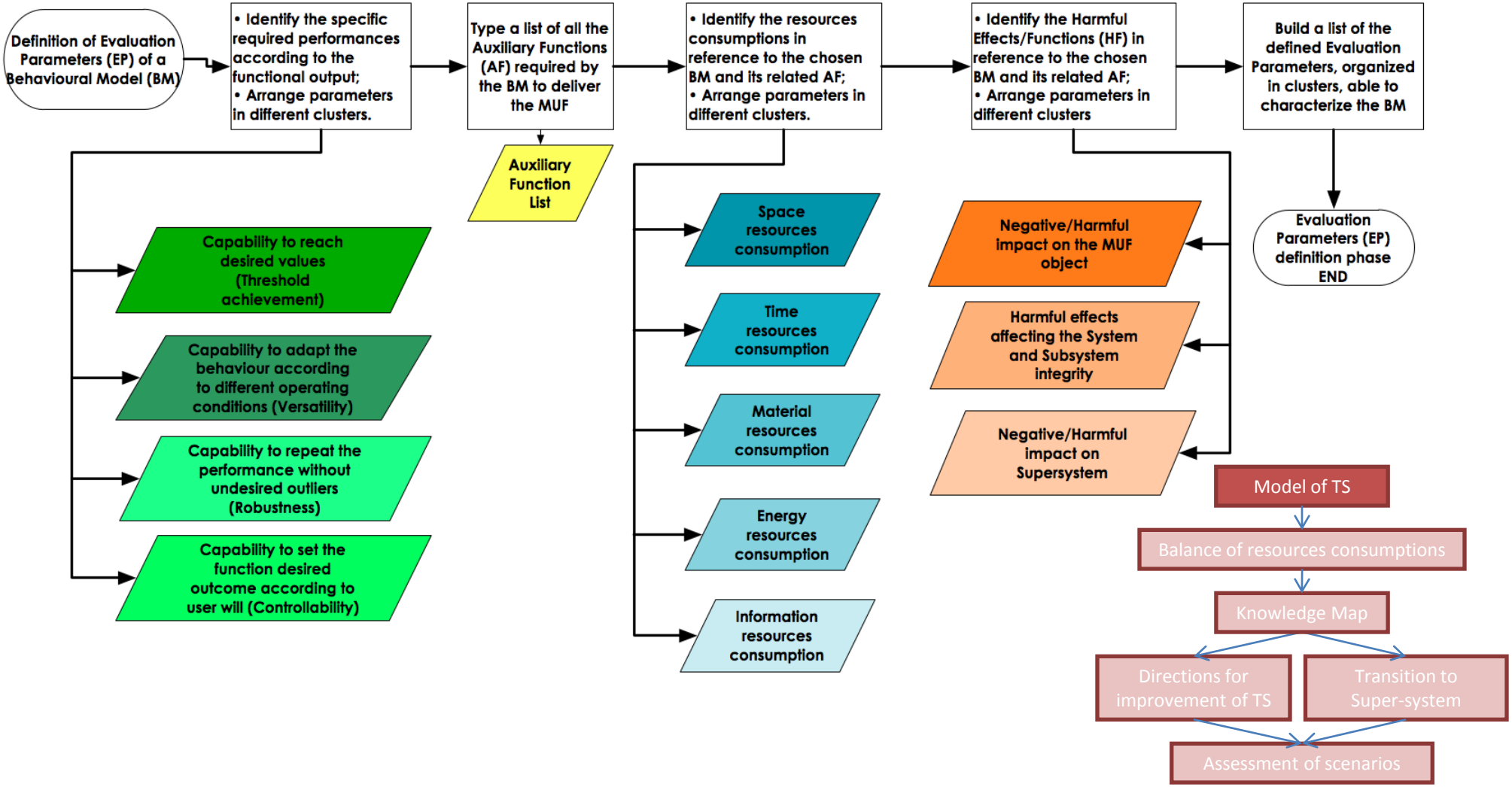
① Parameters strictly involved in the consumption of resources

② Parameters that can be in conflict with, or strictly related to, parameters of class 1

③ Parameters with poor or no pertinence at all within the Green Kitchen Project

EP classification

- Algorithm for EP classification [6]:



[6] Becattini N., Cascini G., Rotini F.: "Correlations between the evolution of contradictions and the law of ideality increase", Proceedings of the 9th TRIZ Future Conference 2009 – Timisoara- Romania, November, 2009.

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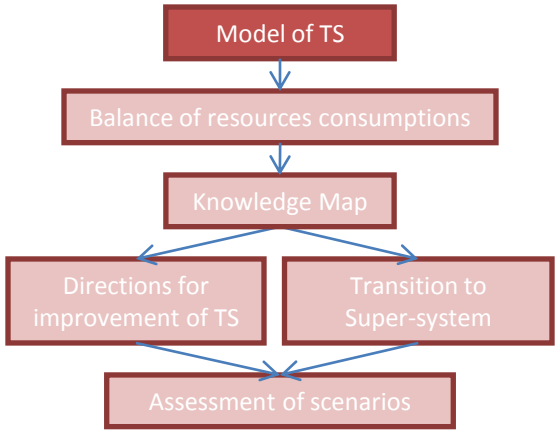
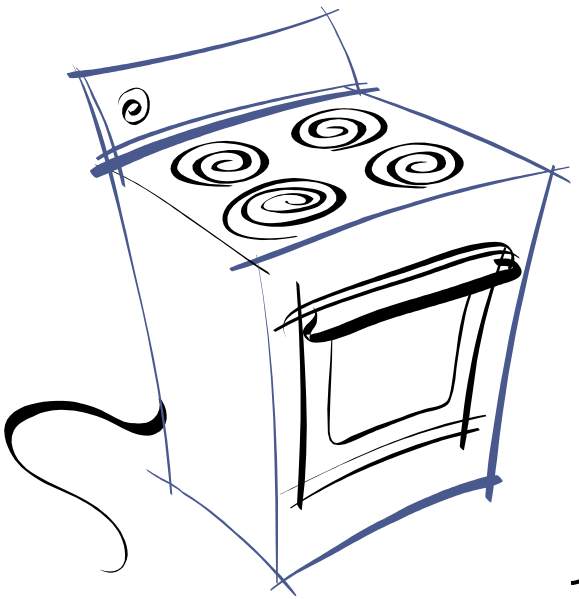
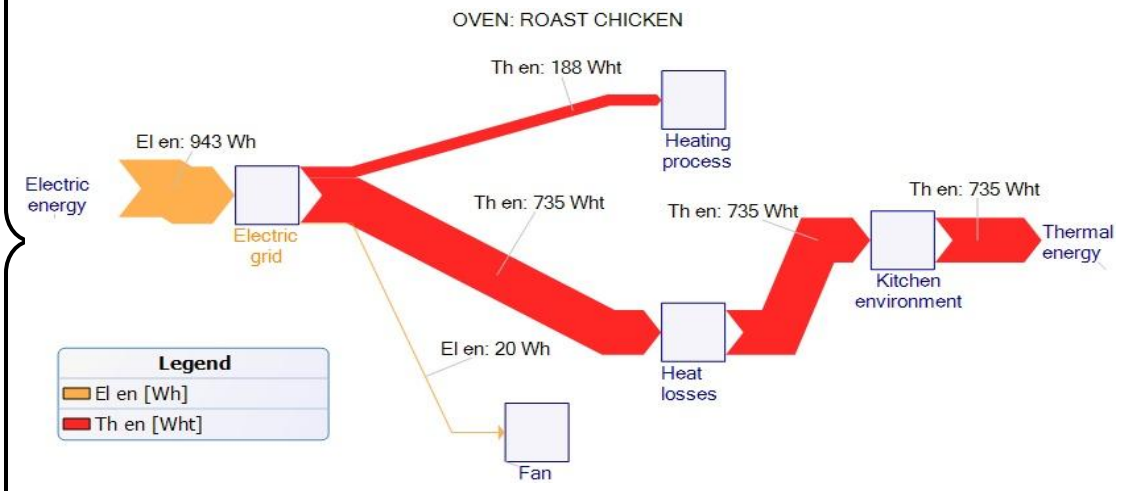


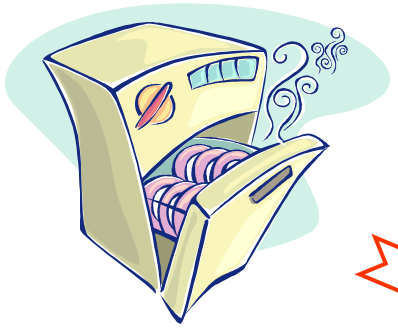


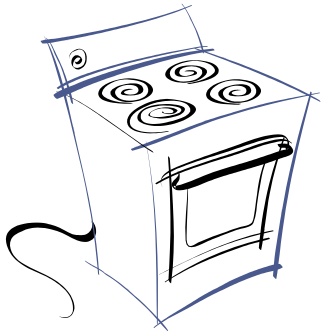


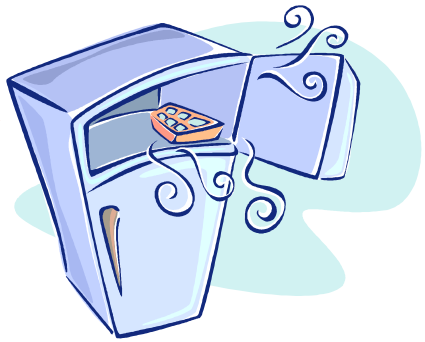
As-Is

Overall balance

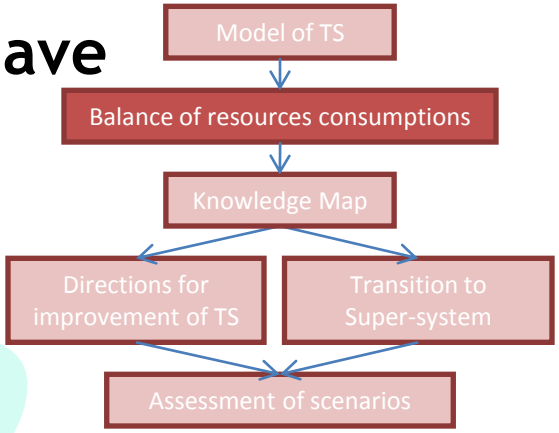
- The Technical Systems of a Domestic Kitchen have different impacts on overall consumptions







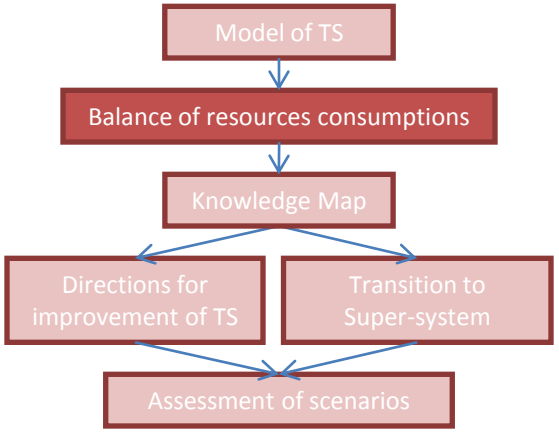
- Working cycles
- Frequency of use
- Off design conditions
- User's habits
- …

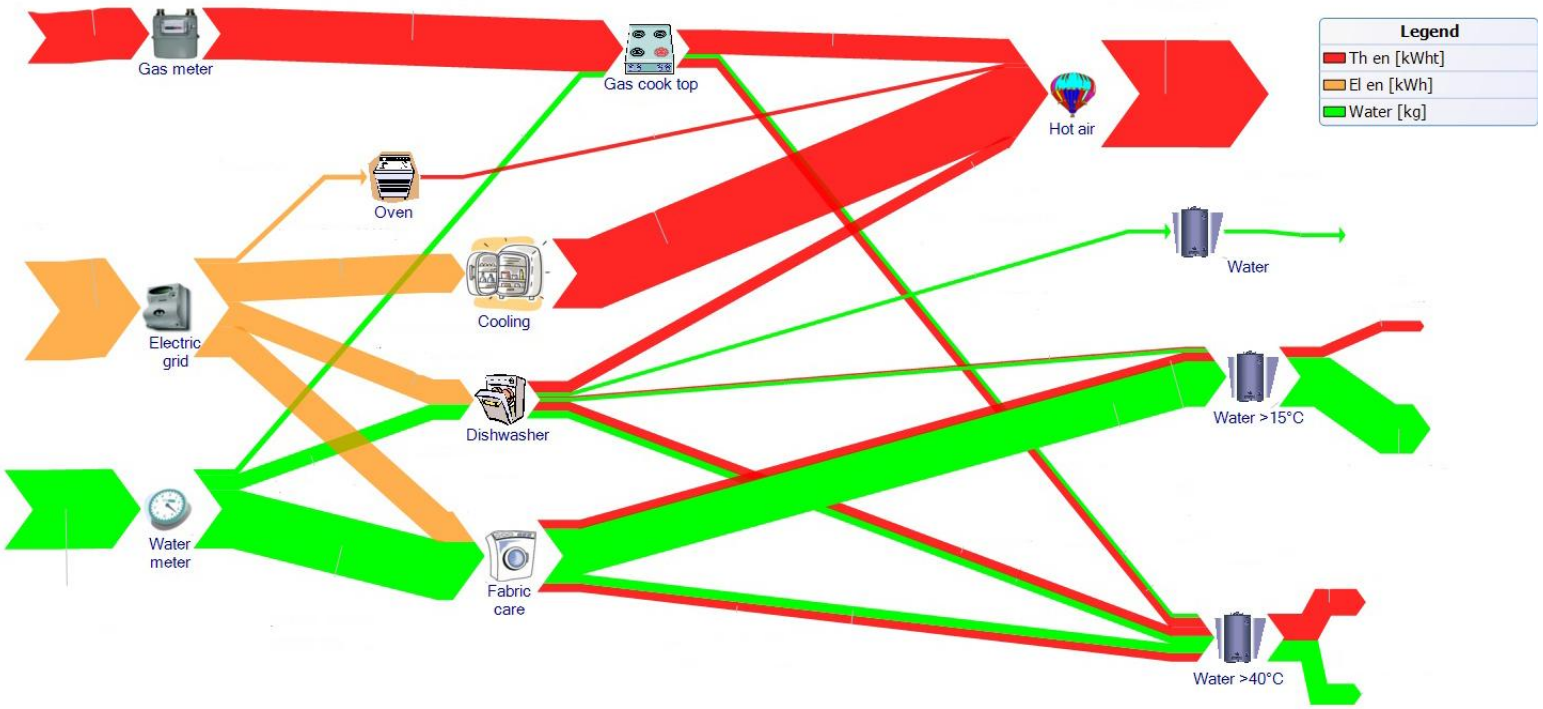


MAIN ISSUE: Definition of Priorities of Intervention

Priorities of intervention

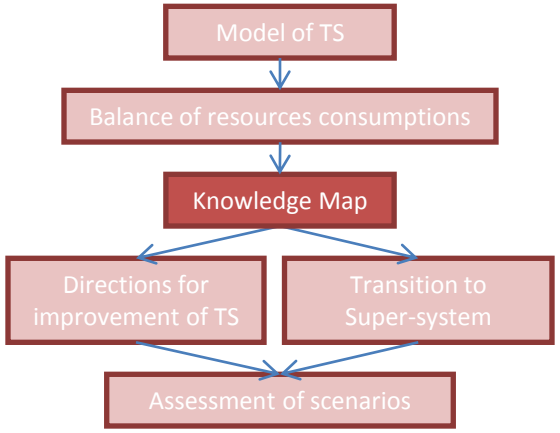
- **Sankey Diagrams allows:**
  - The identification of priorities of intervention
  - The quantification of waste
  - The identification of opportunities for resources sharing among appliances
  - The introduction of a temporal perspective (which is paramount for energy issues)

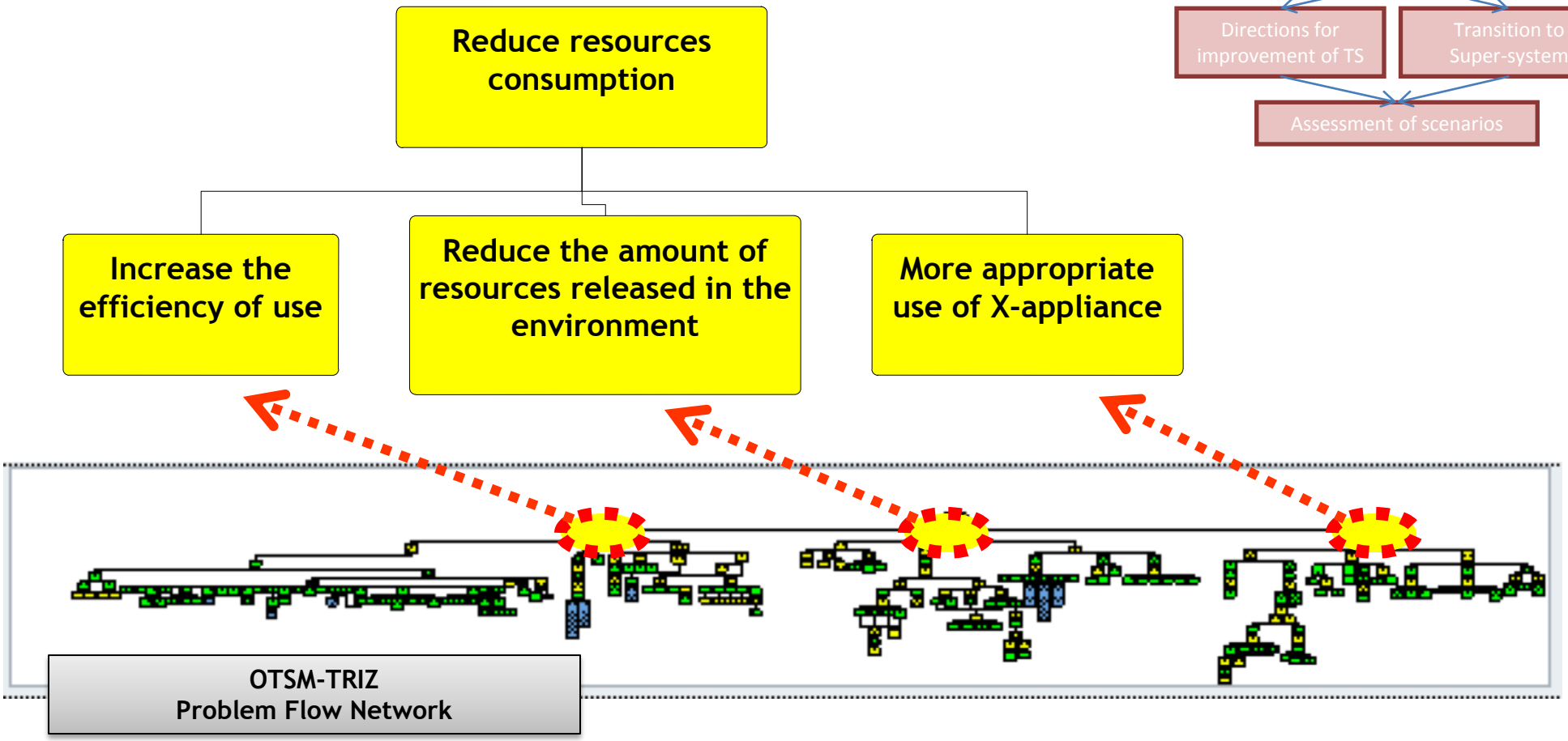




Knowledge map: reduction of resources consumption

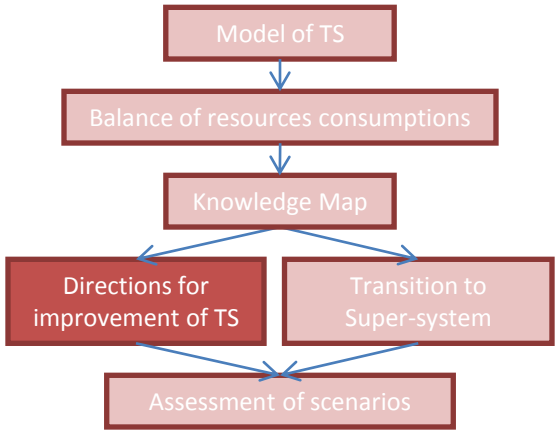
- The reduction of resources consumption may be pursued by means of the three proposed different approaches

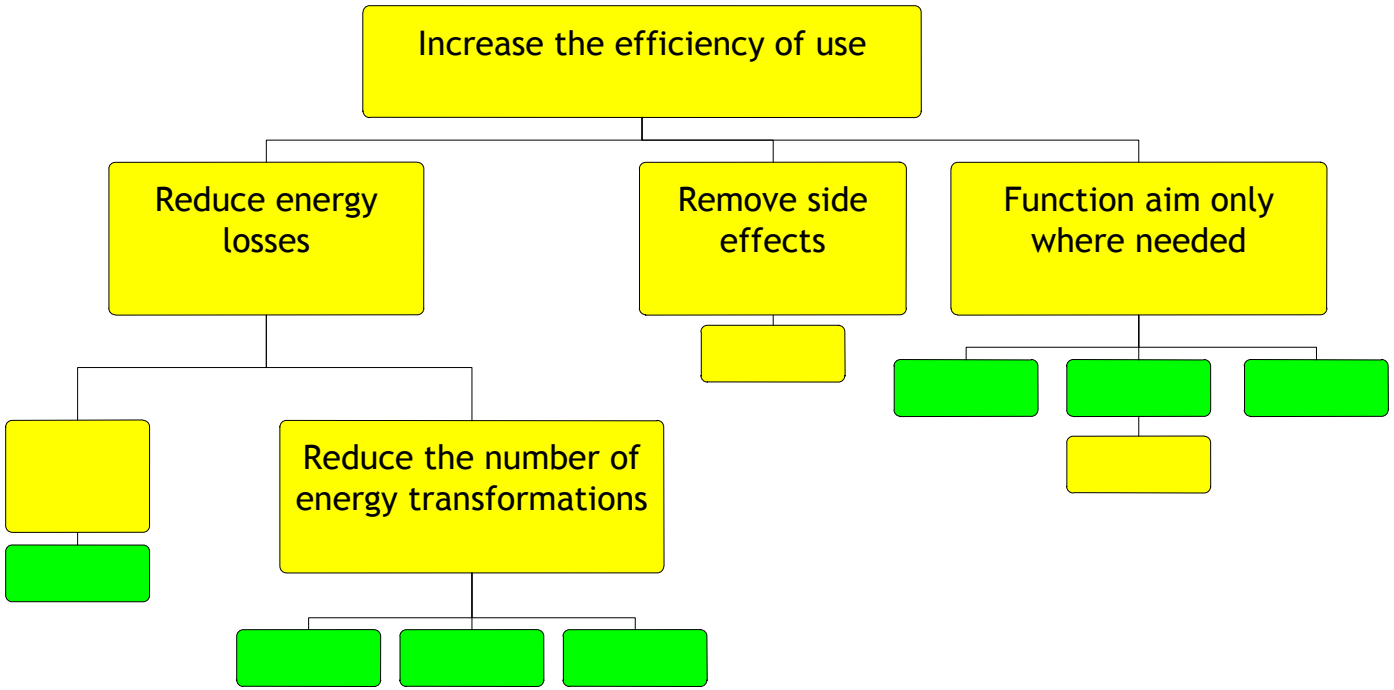




Directions for improving a single TS

- Reduction of resources consumption
  - Efficiency improvement
  - Through the introduction of auxiliary functions
  - Reduction of waste and recovery for reuse





Direct Drive Technology by Samsung and LG

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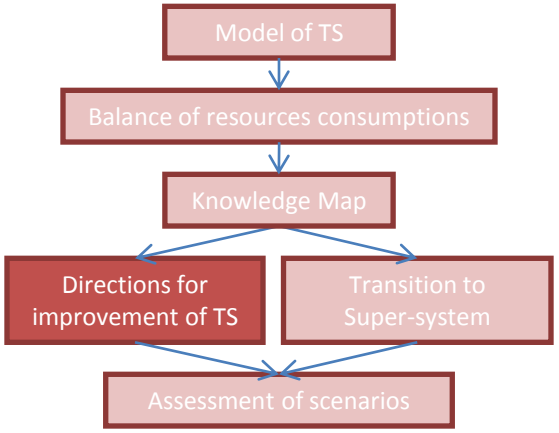
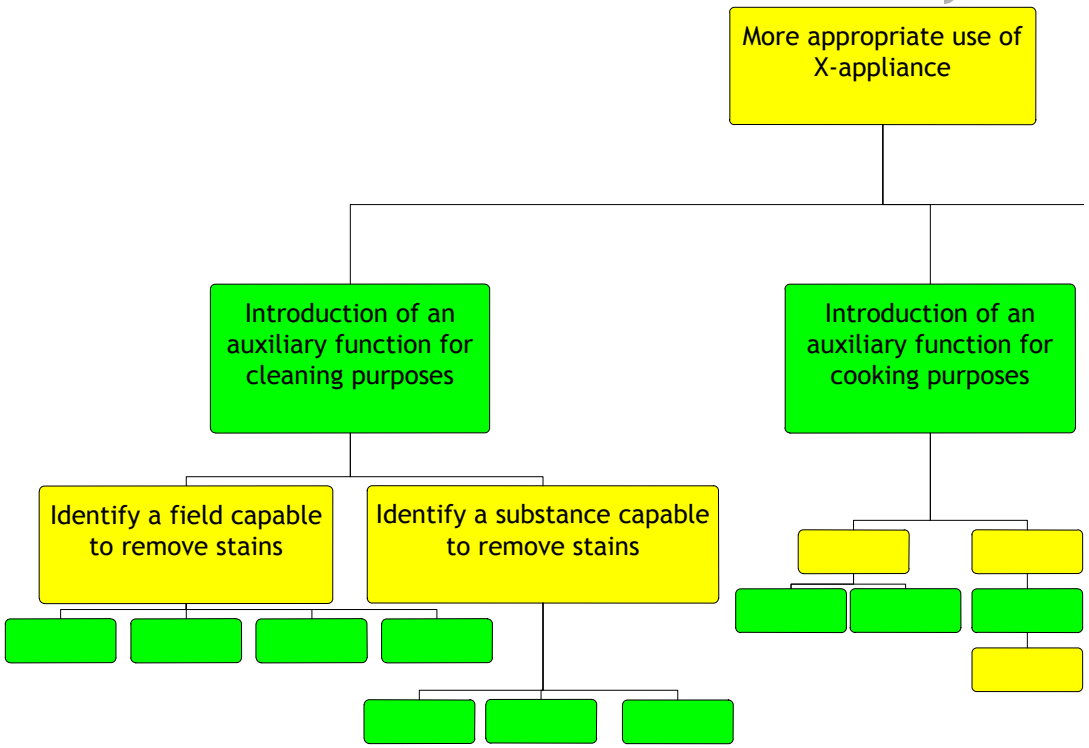
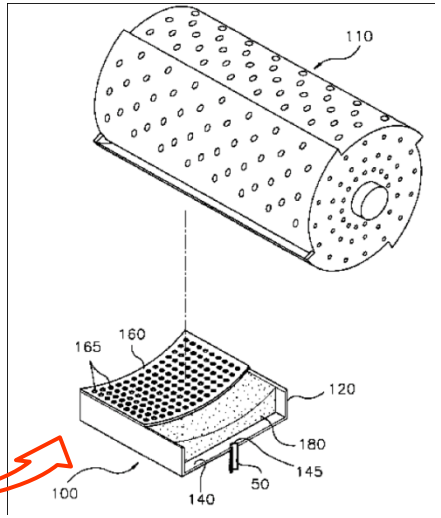




Washing machine with an air bubble generator



Patent US6094948 of Daewoo Electronics (1998)

Directions for improving a single TS

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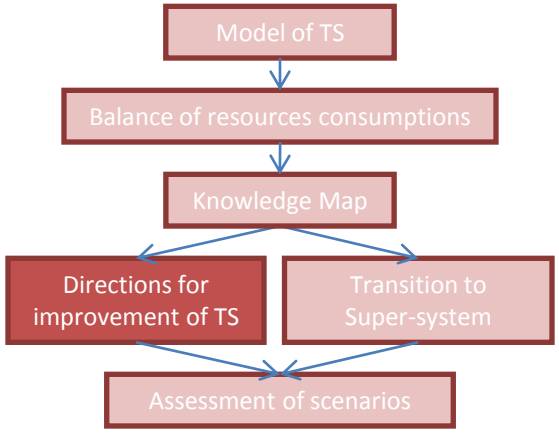
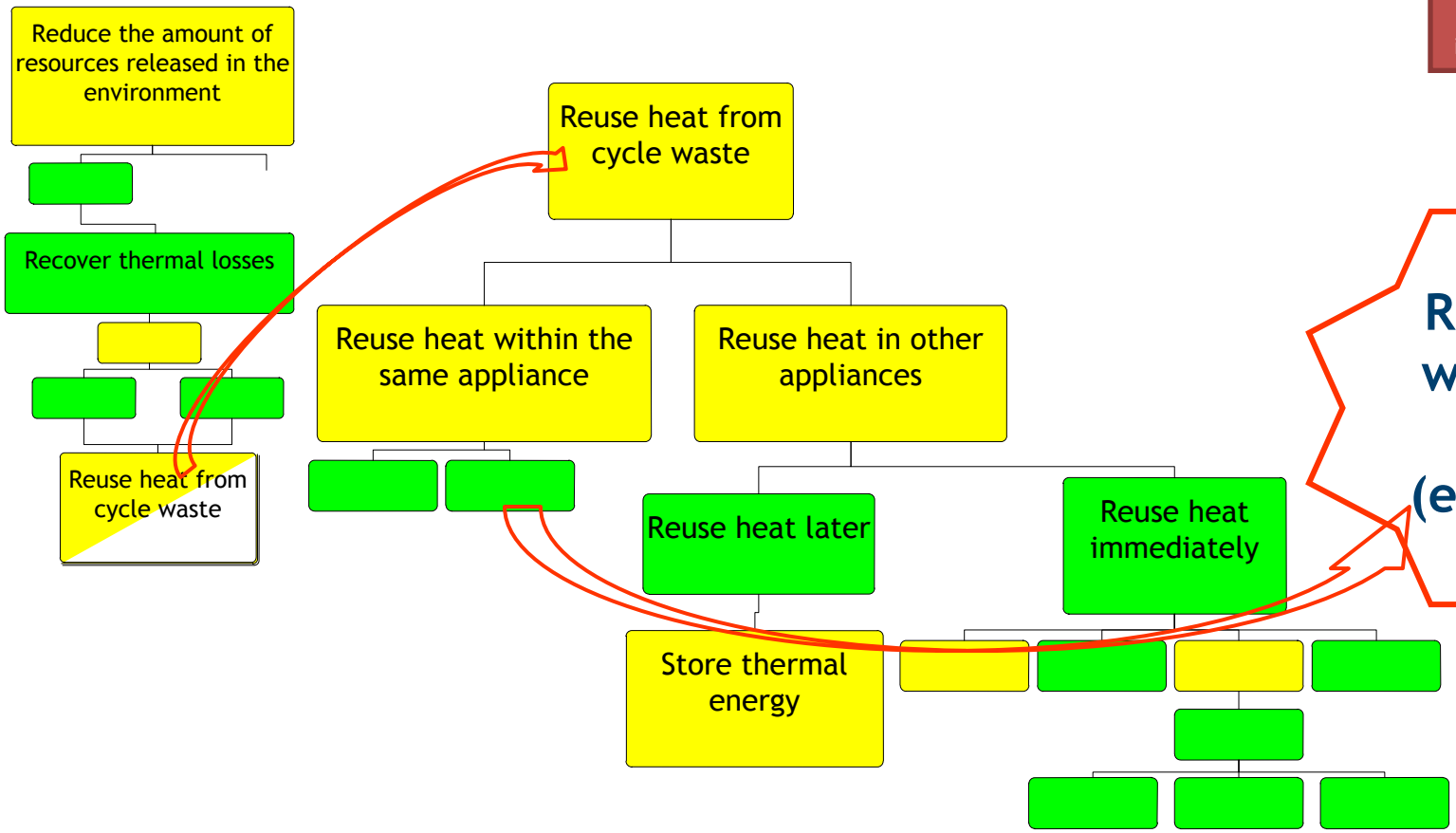
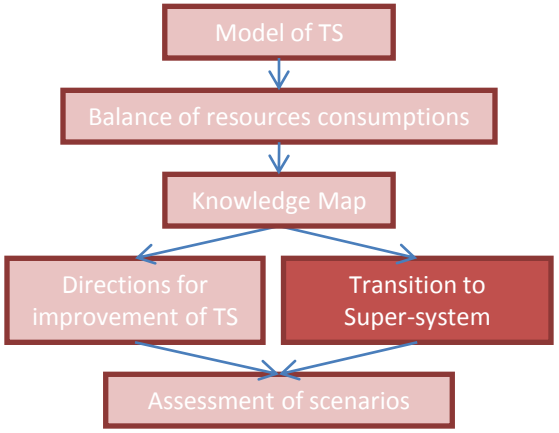




Dishwasher
Reuse heat of the washing phase for postponed use (e.g.: drying phase)

Transitions to supersystem

- Reduction of resources consumption
  - Systems Integration
    - Identify common functions
    - Compare behaviors and identify integrable subsystems
    - Define “mono-bi-poly” appliances/submodules



Appl.	Ref	Element	Function	Object
Dish	1	Spray pump	Increase pressure	Water and detergents
Dish	1.1	Pressurized water	Direct - move	Spray arm

	Possible integration
	Possible integration after
	Several dubts

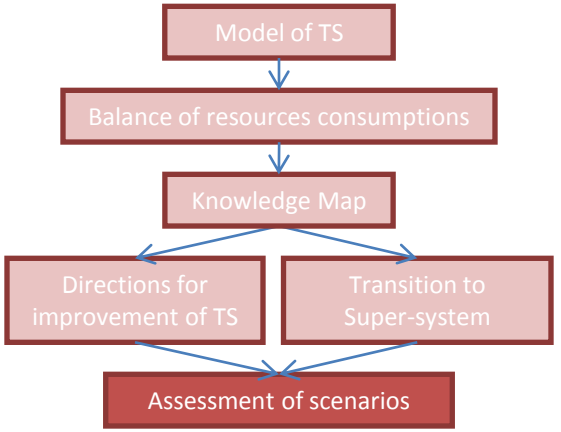
Appl.	Ref	Element	Function	Object	Wash	Wash	Wash	Wash	Wash	Wash	Wash	Wash	Wash	Wash	Wash	Wash	Wash
				Reference	1	1.1	1.1.1	2	3	4							0
				Element	Motor	Drum	Drum	Drum	Dead volume	Heater							
				Function	Move	Move	Move away from clothes	Keep	Collect	Heat							New function
Dish	1	Spray pump	Increase pressure	Water and detergents													I
Dish	1.1	Pressurized water	Direct - move	Spray arm													
Dish	1.1.1	Spray arm	Direct - move	Water - Dishes													
Dish	1.1.2	Spray arm	Carry - move	Detergents													
Dish	2	Heater	Heat	Cold water						E							
Dish	2.1	Hot water	Heat	Dishes													
Dish	2.1.1	Hot dishes	Vaporize - Move away	Water			B										
Dish	3	Softener	Reduce Ph	Water													L
Dish	3.1	Rigenerator	Rigenarate	Salt													
Dish	4	Sump	Collect	Water and detergents					D								
Dish	5	Racks	Keep	Dishes				C									
Dish	6	Drain pump	Move	Dirty water and particles									F				
Dish	7	Filter	Filter	Water										G			
Dish	8	Insulating material	Thermal insulate	Case													
Dish	0		New function			A										H	

Appliance	Wash	Wash
Reference	1	1.1
Element	Motor	Drum
Function	Move	Move
Object	Drum	Clothes -Water

Assessment of scenarios

- **Number of promising directions of evolution**

Resource / Appliance	Water	Thermal Energy	Electric Energy	Total
Dishwasher	13	7	9	**29**
Washing Machine	10	5	10	**25**
Oven	//	10	4	**14**
Cooktop	//	3	3	**6**
Refrigerator	//	16	9	**25**
Total	**23**	**41**	**35**	99



- **Expected savings of resources (max)**

Resource / Appliance	Water		Thermal Energy		Electric Energy	
	Cycle	Weekly	Cycle	Weekly	Cycle	Weekly
Dishwasher	-25%	-5%	-13%	-3%	n.a.	n.a.
Washing Machine	-24÷32%	-18÷24%	-60÷73%	-47÷58%	-0,3÷2,2%	-0,01÷0,09%
Oven	//	//	n.a	n.a	n.a	n.a
Cooktop	//	//	n.a.	n.a	n.a.	n.a.
Refrigerator	//	//	-10÷50%	-4÷20%	n.a.	n.a.

Conclusions

- Advantages of the proposed Step-by-Step Algorithm
  - User oriented modeling of functions
  - System Thinking
    - Model of resources consumptions at different detail level
    - Knowledge Map suitable for all the appliances
  - Quantitative criteria for the definition of priorities of intervention
    - Immediate feedback about relevance of Technical Contradictions
    - Quantitative criteria for the assessment of evolutionary scenarios
- Future steps
  - Start virtual/experimental validation of a selection of the proposed scenarios
  - Define a step-by-step procedure for guiding the application of the proposed roadmap in different contexts
  - Develop a Computer-Aided tool based on the proposed procedure