



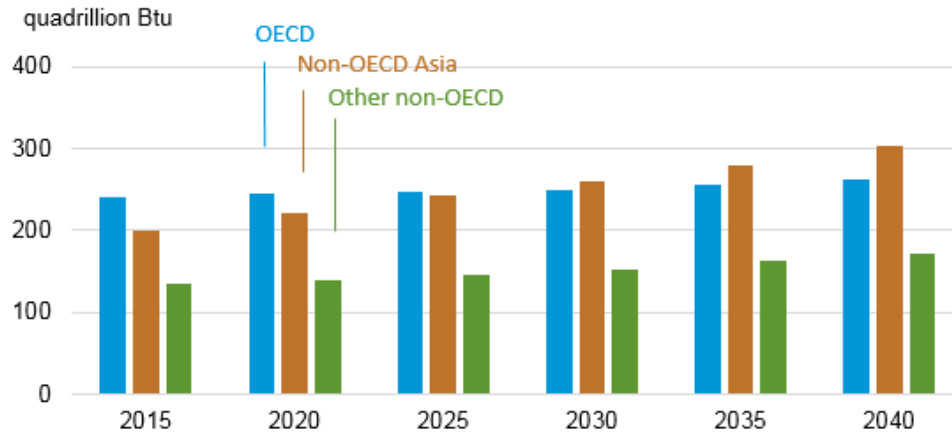
Compressed air systems: factors affecting the adoption of measures for improved efficiency

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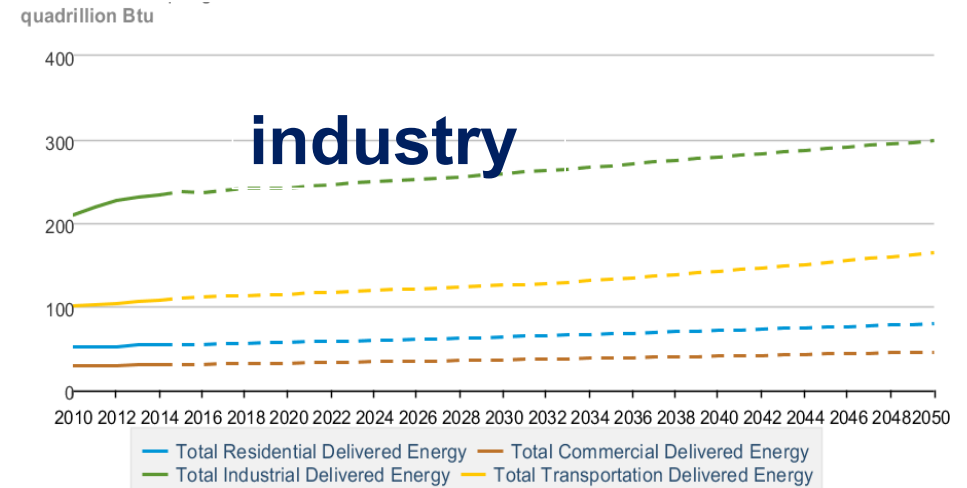
Prof. Enrico Cagno, Politecnico di Milano

Marco Nicosia, Politecnico di Milano

Energy consumption



World energy consumption: 2015-2040 horizon



Sectorial consumption: 2015-2050 Horizon

Energy efficiency



Savings



Increased productivity



Waste minimization



Pollution prevention

Why talking about CAS?

- **Widespread** in all manufacturing plants
- It is not a productive output, since mainly used as a service; it is an **invisible technology**
- Important for correct operations of other systems
- It extends in different parts of the plant
- Difficulties embedded in the implementation of interventions are revealed to be the major barriers hindering adoption of EEMs



Need for a support tool, to **handle** at best the **decision**

FURTHER SUPPORTED BY

IAC interventions' database

24289 recommendations
Implementation Rate < 60%

Why talking about CAS?

ARC code	EEM	Recommendation	% impl.
2,4236	ELIMINATE LEAKS IN INERT GAS AND COMPRESSED AIR LINES/ VALVES	8138	80.38
2,4221	INSTALL COMPRESSOR AIR INTAKES IN COOLEST LOCATIONS	5129	46.5
2,4231	REDUCE THE PRESSURE OF COMPRESSED AIR TO THE MINIMUM REQUIRED	4446	49.6
2,2434	RECOVER HEAT FROM AIR COMPRESSOR	1626	31.86
2,4232	ELIMINATE OR REDUCE COMPRESSED AIR USED FOR COOLING, AGITATING LIQUIDS, MOVING PRODUCT, OR DRYING	1450	46
2,4226	USE / PURCHASE OPTIMUM SIZED COMPRESSOR	692	42.92
2,4224	UPGRADE CONTROLS ON COMPRESSORS	639	44.6

Towards the new framework: integrating multiple info sources

THE FRAMEWORK COMES FROM TWO DIFFERENT LITERATURE STREAMS

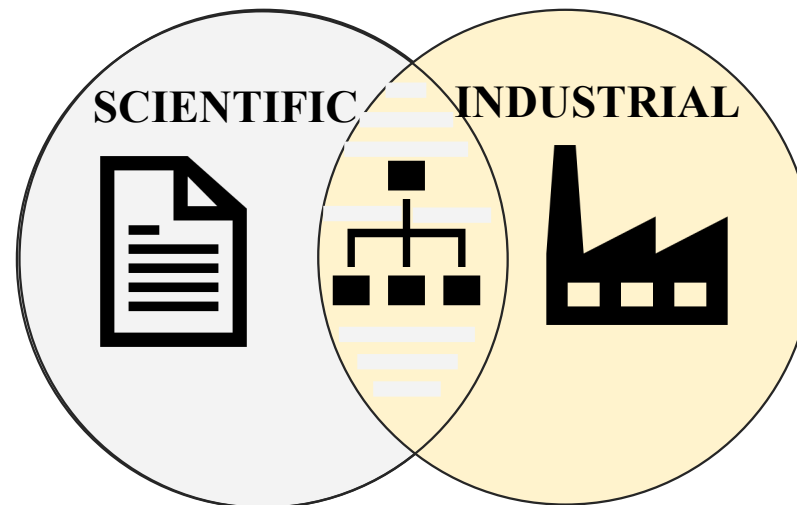
EEMs Related

Single characteristics

Categories of factors

Technology Related

List of factors,
characteristics



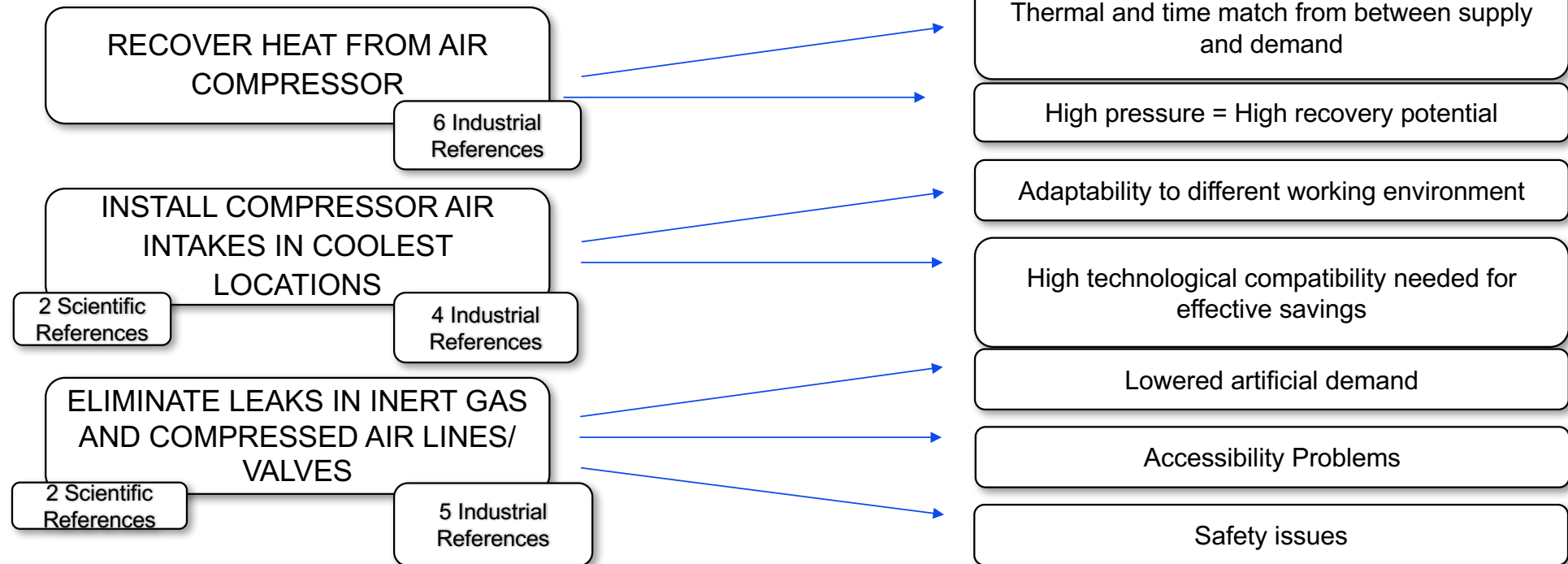
Technology Related

Technology suppliers

Compressed air energy
efficiency manuals

Towards the new framework: the approach

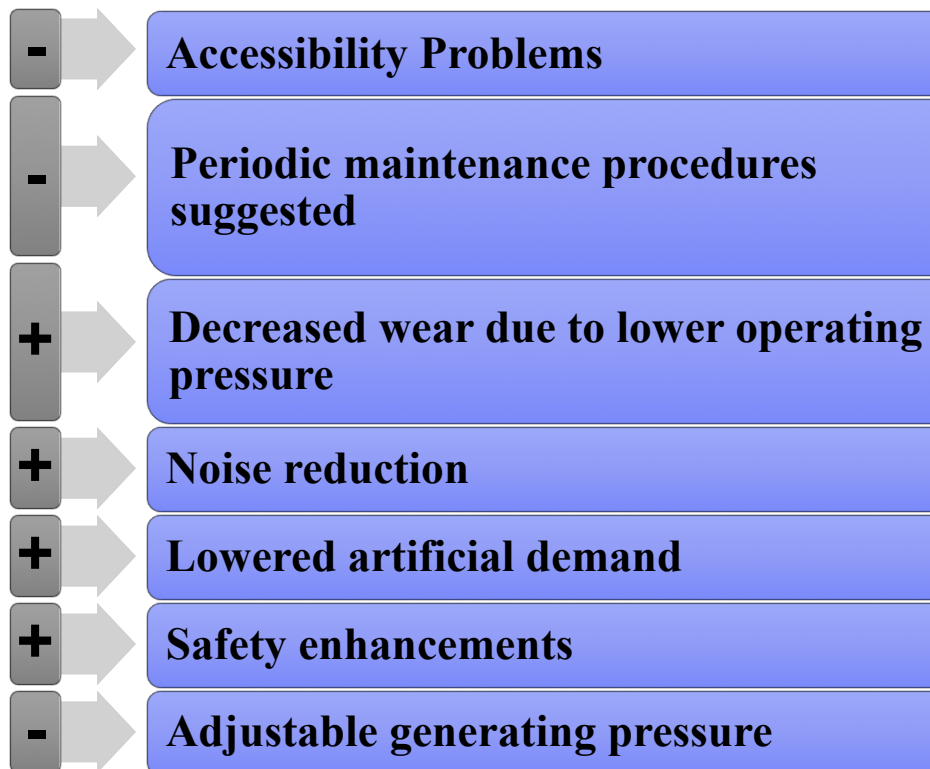
Total of 16 EEMs



Towards the new framework: the approach

ELIMINATE LEAKS IN INERT GAS AND COMPRESSED AIR LINES / VALVES

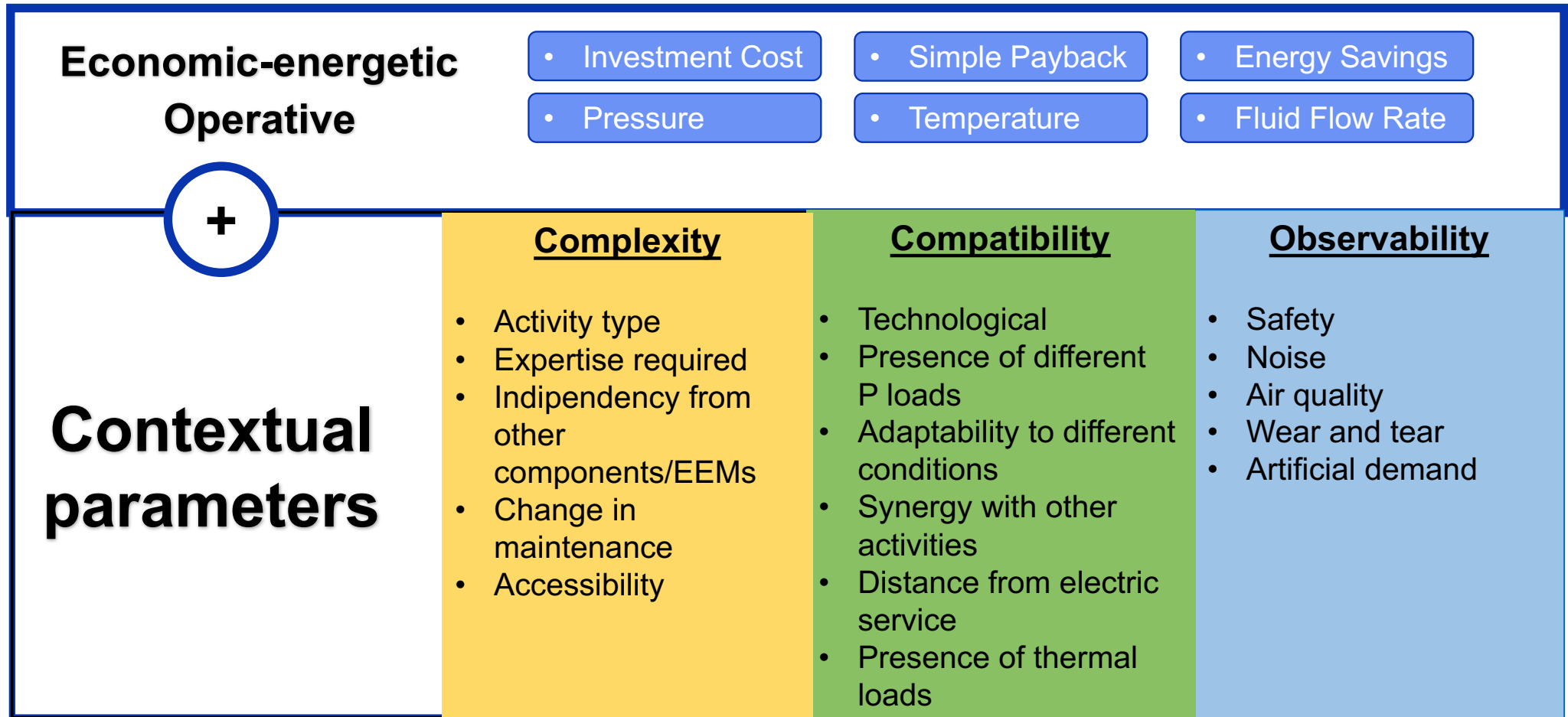
INFLUENCING FACTORS



LITERATURE

- I Improving Compressed Air System Performances: a sourcebook for industry. **U.S. DOE**
- I White paper, reducing energy costs in compressed air systems by up to 60%. **Festo online**
- I White paper, reducing energy costs in compressed air systems by up to 60%. **H. Van Ormer for airbestpractices**
- I Reducing your leak rate without repairing leaks. **C.E. Beals for airbestpractices**
- I PCE compressed air leak surveys for the petrochemical industry. **R. Smith for airbestpractices**
- S Energy conservation in compressed-air systems. **D. Kaya, P. Phelan, D. Chau, H.I. Sarac**
- S A review on compressed-air energy use and energy savings. **R. Saidur, N.A. Rahim, M. Hasanuzzaman.**

The new framework: Macro-categories



The new framework: Complexity

It is the degree of difficulty perceived when a measure is going to be adopted, and the increase of the complexity is generally negatively correlated with the adoption of an EEM .

Activity Type	<ul style="list-style-type: none">• Represents the activity that is going to be performed to implement the EEM
Expertise Required	<ul style="list-style-type: none">• Refers to the degree of knowledge required for the EEM adoption, can range from simple maintenance procedures to needs for technology experts
Independency from other components/ EEMs	<ul style="list-style-type: none">• Represents how the implementation of the measure is influenced by other systems
Change in maintenance	<ul style="list-style-type: none">• Refers to the change in maintenance procedures
Accessibility	<ul style="list-style-type: none">• Represents the problem of accessing some points

The new framework: Compatibility

It explains to which degree the EEM can be adapted to existing system conditions.

Technological	<ul style="list-style-type: none">• Technological constrains or opportunities for the adoption of some EEMs
Presence of different P loads	<ul style="list-style-type: none">• The presence of this condition in the system, influences EEMs
Synergy with other activities	<ul style="list-style-type: none">• Represents the coordination of performing some of the implementation procedures with similar types of activities i.e. maintenance, requiring downtime
Adaptability to different conditions	<ul style="list-style-type: none">• Adaptability is strictly related to the flexibility concept; this can be referred to the capability of adapting to load variations (seasonal workload) or to future system modifications.
Distance to the electric service	<ul style="list-style-type: none">• This factor refers to the compatibility of some technology substituting compressed air, for which is required closeness to the electric service
Presence of thermal loads	<ul style="list-style-type: none">• The presence of thermal loads influences the possibility of installing some efficiency measures since it is related to the energy and time match between the supply and demand

The new framework: Observability

It represents how an EEM, once implemented, can be perceived within the production context

Safety	<ul style="list-style-type: none">• Refers to the changing of safety conditions inside the plant
Noise	<ul style="list-style-type: none">• Refers to the changing of how much noise is perceived in the production context
Air Quality	<ul style="list-style-type: none">• Refers to the compressed air quality level
Artificial Demand	<ul style="list-style-type: none">• Is the additional demand required in the system for acting at a higher pressure with respect to the one required
Wear and tear	<ul style="list-style-type: none">• Represents wear conditions of components and, as consequence, is also strictly related to their lifetime

Application to manufacturing companies

- **11** sampled companies, **15** different EEMs
- High differences could outline a **lack of awareness** on the specific value of a factor (for further analysis)
- If some of the factors are totally neglected, the framework application should be perceived as **strategic**
- **User-friendliness** and **effort** are the selected KPIs

	User-friendliness	Effort
Respondents	11	11
Evaluated as 4/4	9	11

Novel framework: an example

Company information

- Sector: Food and Beverage
- Turnover: 48 M€
- 104 employees

Type of compressor	Power [kW]	Control	Function
Screw-lubricated	60	Load-Unload	Service
Screw-lubricated	40	Load-Unload	Service
Screw-lubricated	40	Load-unload	Backup
Screw-lubricated	22	VSD	Service

Last efficiency measures adopted	Year	Cost investment
Install adequate dryers to eliminate blowdown	2016	Medium
Eliminate air leaks	2016	Low

Novel framework: an example

THE NEW EEM IN A NUTSHELL

Technology substitution from vacuum generators to electric vacuum pump

EEM (as defined by IAC)

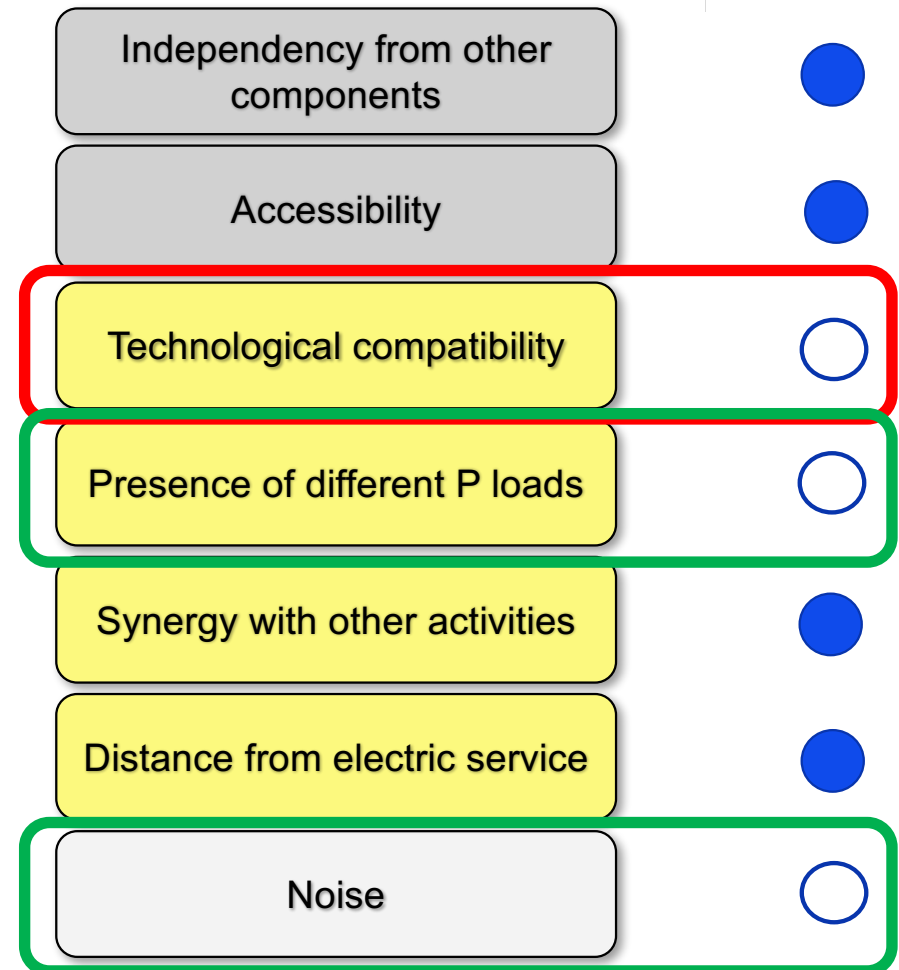
Eliminate or reduce the compressed air used for cooling, agitating liquids, moving product or drying

STATUS QUO

EEM not implemented for lack of time and risk of production disruption (now no 24/7 basis)

FINDINGS

1. Increased awareness;
2. Possible positive outcomes not accounted before



Concluding remarks

In a nutshell:

- ✓ Structure complete
- ✓ Good potential as support tool for industrial decision-makers.
- ✓ Increasing knowledge in recognizing EEMs that can go beyond cost-benefits analysis
- ✓ **Pointing out benefits so far hidden**

Ongoing work...

- Extend the sample to different clusters of enterprises (contextual factors, different use of compressed air)
- Extension to other high efficiency potential technologies
- Use of this framework as a basis for an assessment tools, evaluating drivers and barriers for each of the EEMs
- Extension to technology suppliers helping to recommend the most suitable EEMs

