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Energy study of a manufacturing plant

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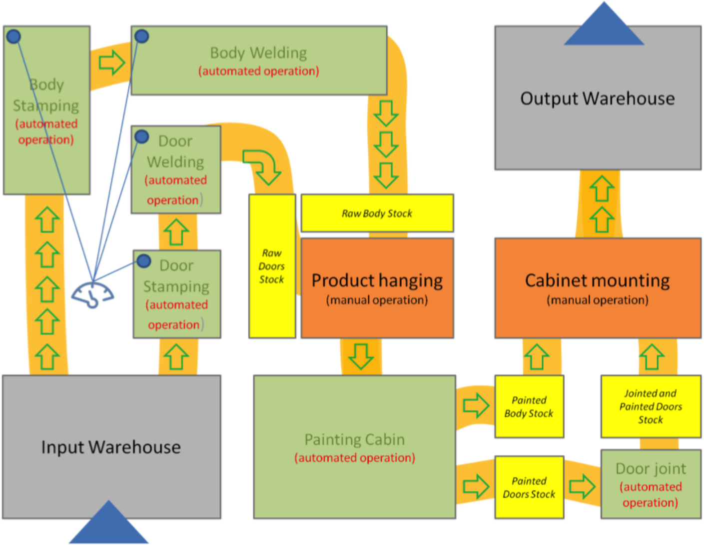
A manufacturing plant of electrical cabinets



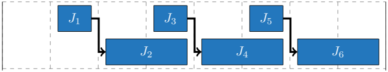
Goal: challenge the inventory policy

1M€ annual electricity bill

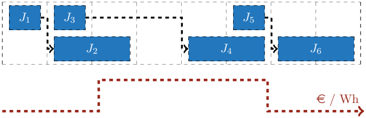
→ $

+

zero stock strategy [1]



energy optimization



[1] Y. Sugimori et al. (1977). "Toyota production system and Kanban system Materialization of just-in-time and respect-for-human system". In: **International Journal of Production Research** 15.6, pp. 553–564

Energy modeling: a state of the Art

- a modelling framework for machine-tool energy consumption

  A Dietmair and A Verl (2009). "Energy consumption forecasting and optimisation for tool machines". In: **Energy** 62, p. 63

- an approach to reduce the number of required sensors in process tracking

  Cao Vinh Le et al. (2013). "Classification of energy consumption patterns for energy audit and machine scheduling in industrial manufacturing systems". In: **Transactions of the Institute of Measurement and Control** 35.5, pp. 583–592

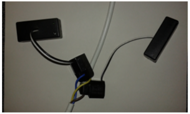
- a generalized approach to manufacturing energy efficiency at: Process level, Machine level, Production line level and Factory level

  Apostolos Fysikopoulos et al. (2014). "On a generalized approach to manufacturing energy efficiency". In: **The International Journal of Advanced Manufacturing Technology** 73.9-12, pp. 1437–1452

Energy Data acquisition system

Self powered energy sensors

Three-phased



Mono-phased

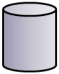
ZigBee

ZigBee to Modbus gateway

Modbus

Custom gateway implementing CEA LINC middleware [1]

FTP



Database and visualization tools

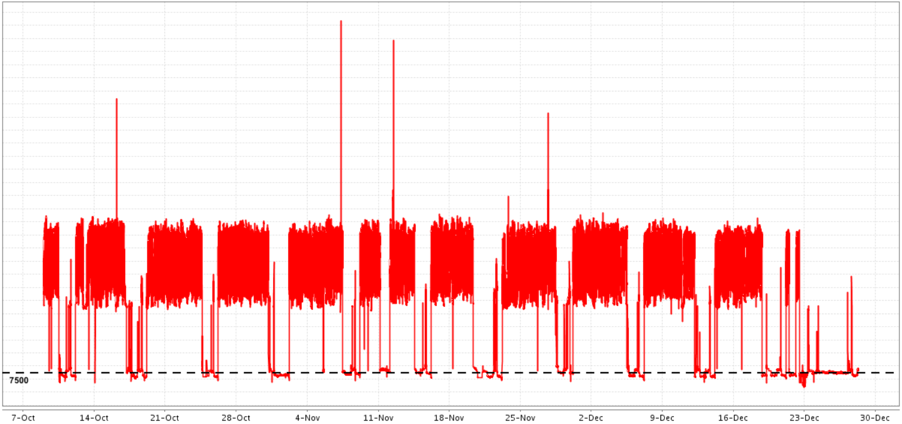
Energy measurement emission triggered by energy quantum

Energy collection loop
1 second sampling rate, reporting only changes

Transmission loop
1 hour cycle time

[1] Maxime Louvel and François Pacull (2014). "LINC: A Compact Yet Powerful Coordination Environment". In: **Coordination Models and Languages: 16th IFIP WG 6.1 International Conference, COORDINATION 2014, Held as Part of the 9th International Federated Conferences on Distributed Computing Techniques, DisCoTec 2014, Berlin, Germany, June 3-5, 2014, Proceedings**. Ed. by Eva Kühn and Rosario Pugliese. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 83–98

A first manual data mining



baseline power: about 7500W

Principles of energy modeling

Time discretization:

Linear regression of:

- $\mathbf{energy_r}$ is the energy consumed by producing one unit of reference r;
- **baseload** is the power consumed by the line whatever the production;
- $\mathbf{error_i}$ is a term that represents regression model errors.

$\forall t_i \leq H,$

$$energy_i = \sum_{r \in References} (\mathbf{energy_r} \times batchSize_{r,i}) + \mathbf{baseload} \times \tau_i + \mathbf{error_i}$$

Results: an energy model

Periods of duration τ

baseload	activities consumption
7.3 kW	bad confidence level

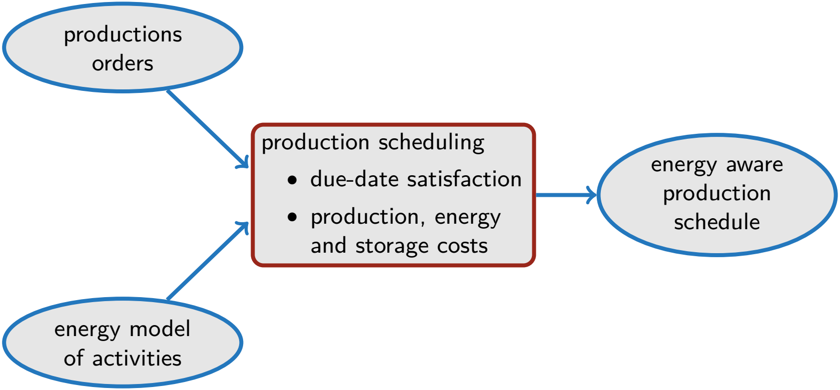
Time periods with similar production aggregated

baseload	activities consumption
very high	variant and realistic

Both strategies combined

baseload	activities consumption
7.3 kW	realistic + high baseload - 7.3 kW [13kW, 23kW]

From energy modeling to production scheduling



First results on benchmarks

Instances

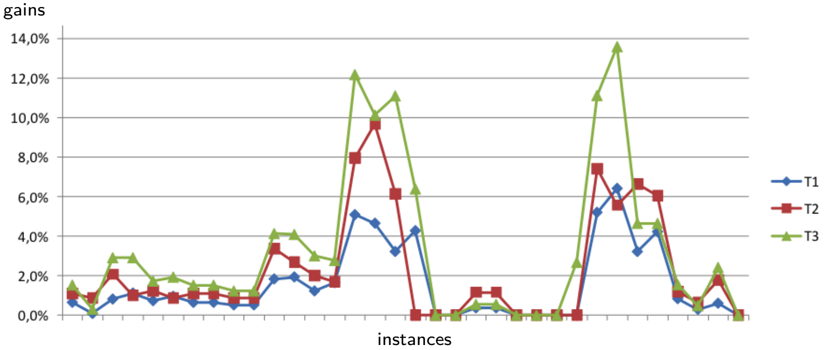
- 34 scheduling problems from academy and industry
- Solved with and without energy taken into account

Tariffs

T1 : basic peak/off-peak tariff

T2 : 30% decrease at night but 7,5% increase at daytime

T3 : 60% decrease at night but 15% increase at daytime



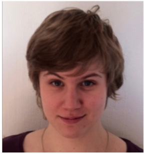
Conclusion and outlooks

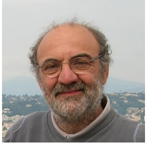
What has been proposed:

- a **methodology** to enable automatic computation of optimal production plans
- the **application** of this method to a real manufacturing plant
- a **scheduling model** of the plant

Outlooks:

- **highlight a correlation** between the width of the cabinet and the energy consumption
- **quantify savings** on the electricity bill
- better **handle disruptions** in data
- **improve scheduling** model to handle big instances


C. Desdouits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Questions?

ARROWHEAD

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