SIMUREX

SIMUlation and **EX**perimentation of the energy performance of buildings

Effin'Art

The Art of Energy Efficiency

Research ←→ Practice

Experience of Research ←→ Practice of Effin'Art (Lausanne) partners (2014 →) including their experience when they were partners at Sorane SA (Ecublens) 1985-2013

Pierre Jaboyedoff

Partner

pierre.jaboyedoff@effinart.ch

www.effinart.ch

+41 21 616 11 00

Effin'Art
The Art of Energy Efficiency

Outline of the presentation
Science ←→ Practice

- Historical perspective of technologies (1985-2018)
- Research projects
- Real buildings and monitored data
- Global situation of energy and CO2 with buildings
  - Focus on hot climates like India

Effin'Art
The Art of Energy Efficiency

Effin'Art

- A «start-up»
- After > 25 yrs at Sorane
- Creation of Effin'Art in 2014
- Partners (ex partners of Sorane SA):
  - Dominique Chuard (Arch. EPFZ) DC
  - Dario Aiulfi (Master mechanical engineering (thermal), PhD ETHZ in Fluid Mechanics) DA
  - Pierre Jaboyedoff (Master mechanical engineering (thermal) EPFL) PJ
  - Other staff also at Sorane before: Mathias Blanc Ing. HES MB
- Cumulative experience ~ 90 years
- Regular use and specific developments of TRNSYS since 1987
- Presentation of Research ←→ Practice activities including work done previously at Sorane SA (DC, DA, PJ,MB)

Effin'Art

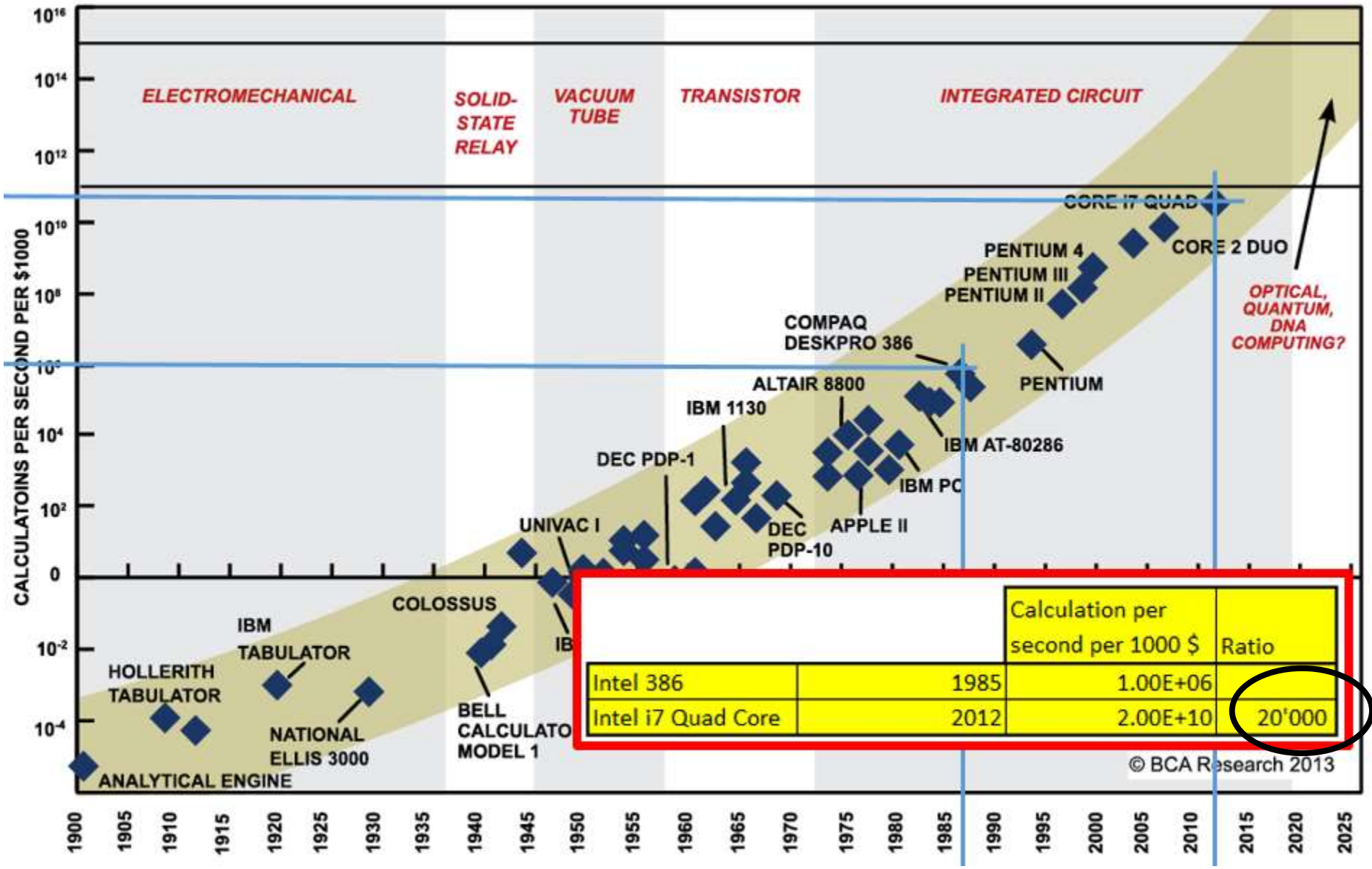
The Art of Energy Efficiency

- Research and software
- Real buildings
- Audit, optimisation
- Programmes, Development project

Effin'Art
The Art of Energy Efficiency

Historical perspective computational means Computer power and cost history

- Increase of computing power 1985-2012 at constant price
  - ~ Factor 20'000
- Application potential for CFD
  - In 1989, 386 ~ 25'000 mesh
  - In 2012, i7 Quad ~16'000'000 mesh
  - **Ratio = 640 times** more detailed models for the same problem ☺



Effin'Art
The Art of Energy Efficiency

Historical perspective computational means (1988)

Macintosh 128 Mb
Excel

RS232

HP Unix 9000

Modem to main frame EPFL 1200 baud

One hourly TRNSYS 13.1 run ~45 minutes

Today 45 seconds on the i7 quadcore laptop

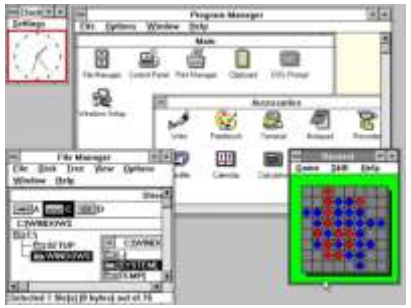
- SOFAS project development and parametric runs system (about 4000 runs)

1. Development on Unix workstation (Fortran 77)
2. Prepare parameters on Macintosh
3. Send by RS232 to Unix
4. Send by modem to CYBER 170 (EPLF)
5. Assemble parametric variation
6. Run parametric simulations (re-compiled on Cyber under NOS/VE) with own batch language
7. Batch for extracting results
8. Back by modem to Unix
9. Back by RS232 to Macintosh
10. Treatment of results

Effin'Art
The Art of Energy Efficiency

- Interface and softwares
  - XEROX PARC late 70's, early 80's

  - Windows 3.0, 1990
  - Windows 95
  - Windows 98
  - Windows 2000
  - Windows 7



  - Windows 10

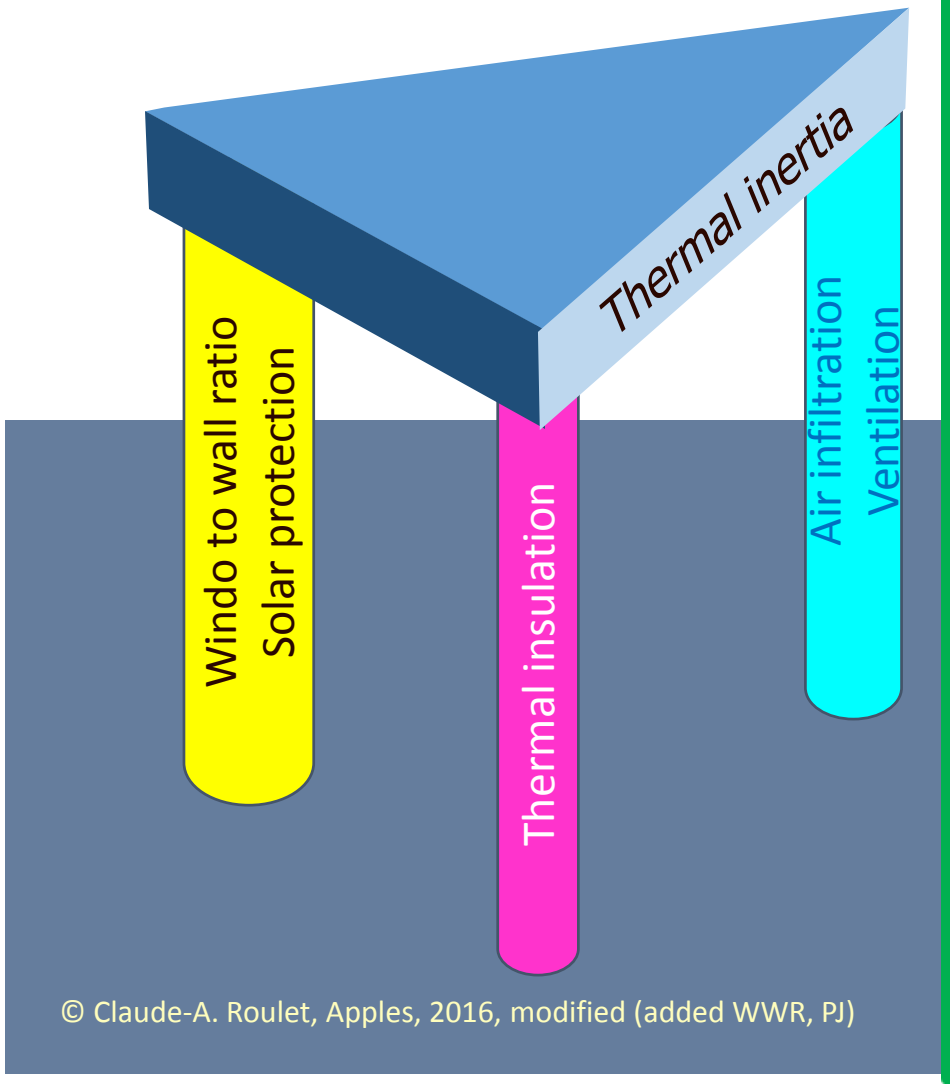
Effin'Art
The Art of Energy Efficiency

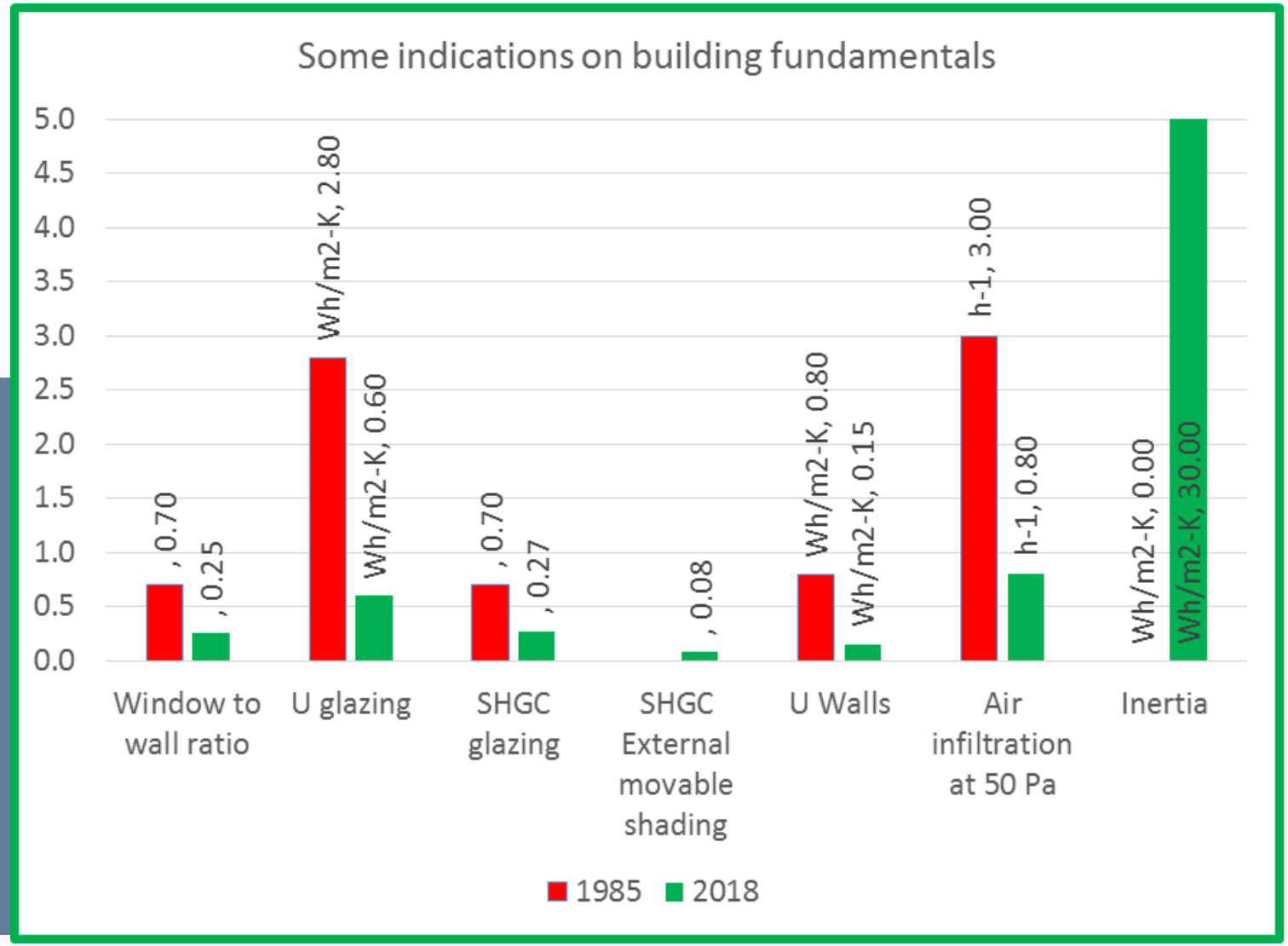
Historical recall of softwares (some of the main in building energy modelling) (free or distributable in green) Science → Practice

- DOE-2: 1978, version 2.2/1998
- TRNSYS 13.1/1990, TRNSYS 14/1994, TRNSYS 15/2000, TRNSYS 16/2005, TRNSYS 17, 2012, TRNSYS 18,
- EES Engineering Equation Solver version 4.2/1996, version 10.509/2018 (EES.exe distributable)
- EnergyPlus: development 1997 → version 1.2.2 /2005,version 7/2015, version 9.0.1/october 2018 (37,000 downloads per update) (public domain)
- CFD Flovent, version 1.2/1991, 3.2/2001, version 12/2017 (VIEWER)
- CFD OpenFOAM, "Open source Field Operation And Manipulation", since 2004, growing list of Graphical User Interfaces

Co-simulation (TRNSED distributable)

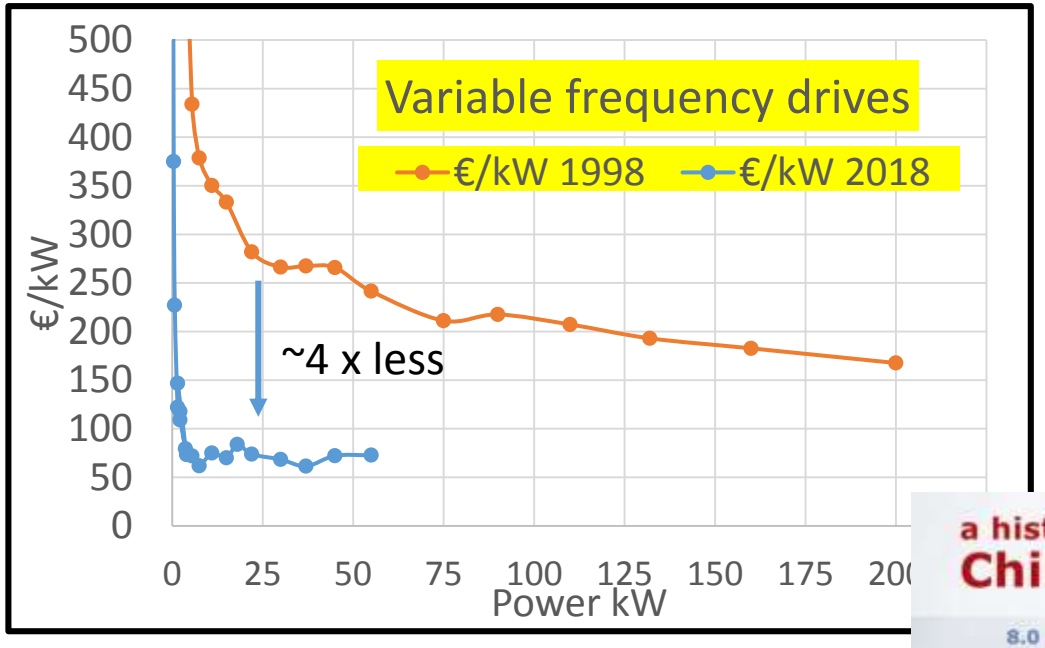
Historical perspective building and technologies Building Energy and Thermal Comfort technology changes 1985-2018 (fundamentals) Science → Practice

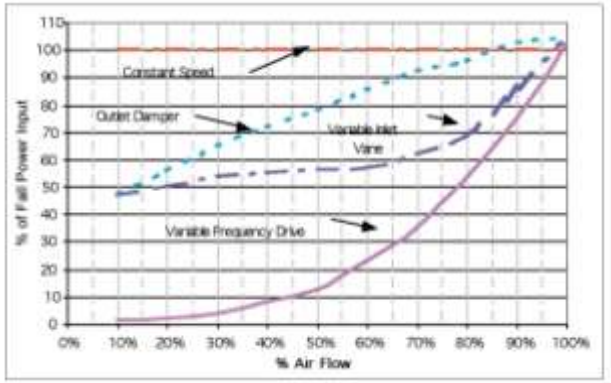




Historical perspective building technologies 1985-2018, some examples, Science → Practice

- Variable frequency drives
  - From on/off to variable flow rate (water and air)
  - Grid problems solved
  - Price reduction by ~4 in the last 20 years
- Chillers
  - COP ~Factor 2 better
  - Even more with a good integrated design
    - Sensible cooling at 14-16 °C
    - High performance condenser cooling (cooling towers, …)
    - Air Handling Units with heat recovery
- Heatpumps
  - COP ~Factor 2 better
  - Even more with a good integrated design
    - Low temperature heating (water max 35 °C
    - Low pressure mechanical ventilation if any
    - Air Handling Units with heat recovery



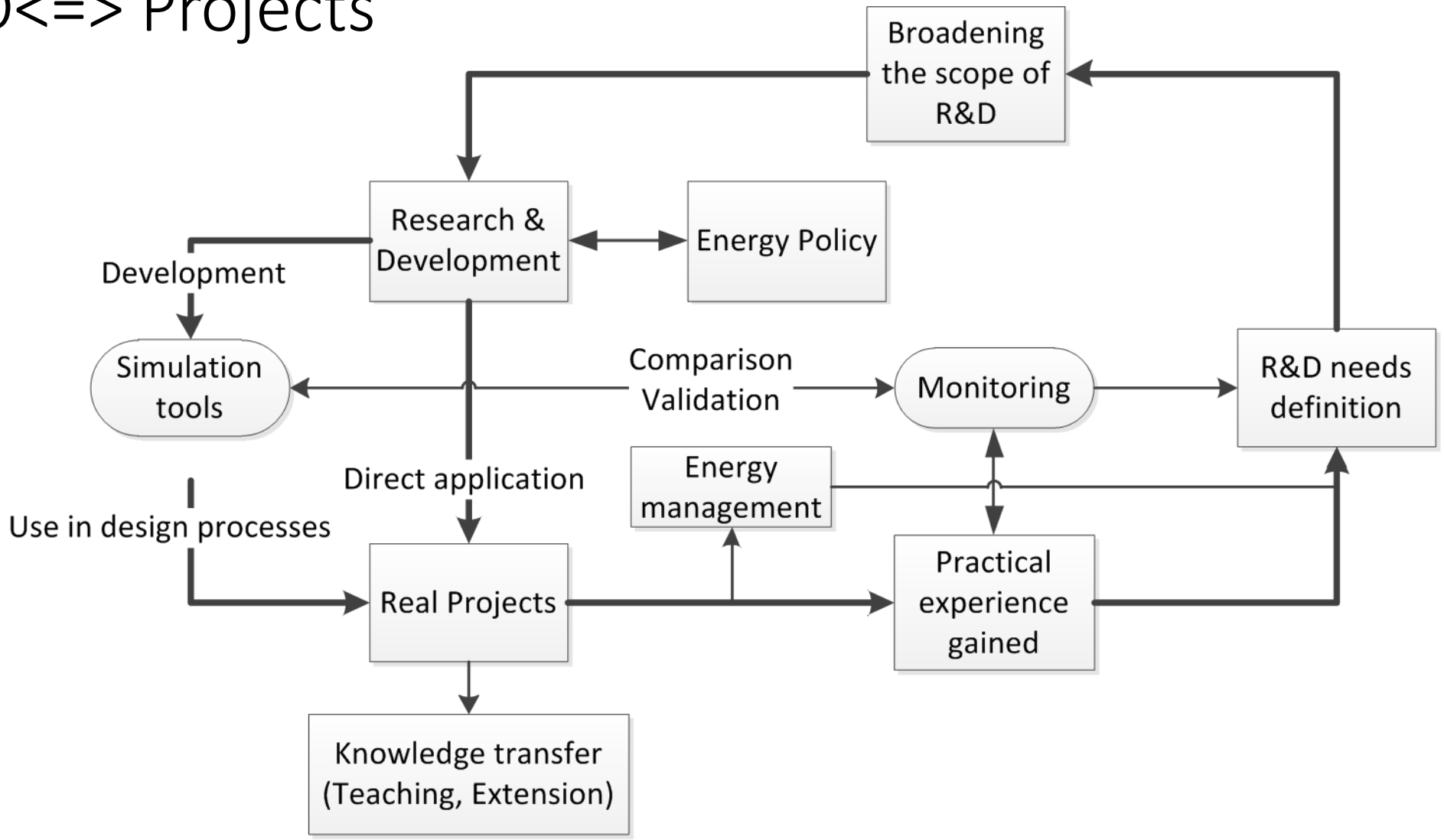


Effin'Art
The Art of Energy Efficiency

Research ←→ Practice as consulting company

Strategy: niche market on energy design: Synergy R&D<=> Projects

- Characterisation of research work for a small private consulting organisation
  - Research is a **part** time activity of the company
  - Time constraints for real projects makes
  - Rather **contribution** than leading research projects
  - Benefit of research network for new topics
  - Application of recent progress in real projects



Effin'Art
The Art of Energy Efficiency

Research ←→ Practice, danger of success

- Often, young consulting companies participate to design competition
- If they win on a large project
  - Strengthen their team with technical staff (drawings, coordination, works)
  - Get a larger staff
- Often shift then to conventional HVAC consulting
- Research and energy efficient design slowly disappear from the practice

Effin'Art
The Art of Energy Efficiency

Research results vectors→ Practice

- Research results vectors toward practice
  - Direct connection
    - Direct → Real projects application (tools and method gained from participation in research projects)
  - Indirect connection
    - Documentation → Practice
    - Training programmes
    - Software re-designed for practice
    - Cooperation projects (example of BEEP)

Effin'Art
The Art of Energy Efficiency

IEA Annex 13 Energy management in hospitals (1985-1989)

- Responsible for the development of the Booklet II

ANNEX XIII - «ENERGY MANAGEMENT IN HOSPITALS»
A GUIDE FOR ENERGY MANAGEMENT IN HOSPITALS

BOOKLET II

HEAT GENERATION AND DISTRIBUTION
COLD GENERATION AND DISTRIBUTION

National Experts

Wes J. Drodge
The Moncton Hospital
135 MacBeath Avenue
Moncton, New Brunswick
CANADA E1C 6Z8

David Harrje
School of Engineering/Applied Science
Centre for Energy & Environmental Studies
The Engineering Quadrangle
Princeton University
Princeton, New Jersey 08544
UNITED STATES

Pierre Jaboyedoff
SORANE s.a.
Consulting Engineers
Rue Chatelard, 52
1018 Lausanne
SWITZERLAND

Hans Blank
Forschungstelle fur Energie Wirtschaft
AM Bruetenanger, 71
8000 München 2
GERMANY

Lothar Rouvel
Technische Universitat Munchen
Arcisstr. 21
8000 München 2
GERMANY

Pierre Desaubies
Marcq & Roba
Consulting Engineers
221 Boulevard Leopold II
1080 Brussels
BELGIUM

Michele Call
Dipartimento di Energetica
Politecnico di Torino
Corso Duca degli Abruzzi, 24
10128 Torino
ITALY

Reviewers and Assistants

Project performed by P. Jaboyedoff when employed by Sorane

Effin'Art
The Art of Energy Efficiency

IEA VII SHC Central Solar Heating Plants with Seasonal Storage (CSHPSS)

- Vaulruz monitoring
  - 500 m2 solar thermal collectors
  - Seasonal duct storage
  - Heat pump
  - Hydronic system

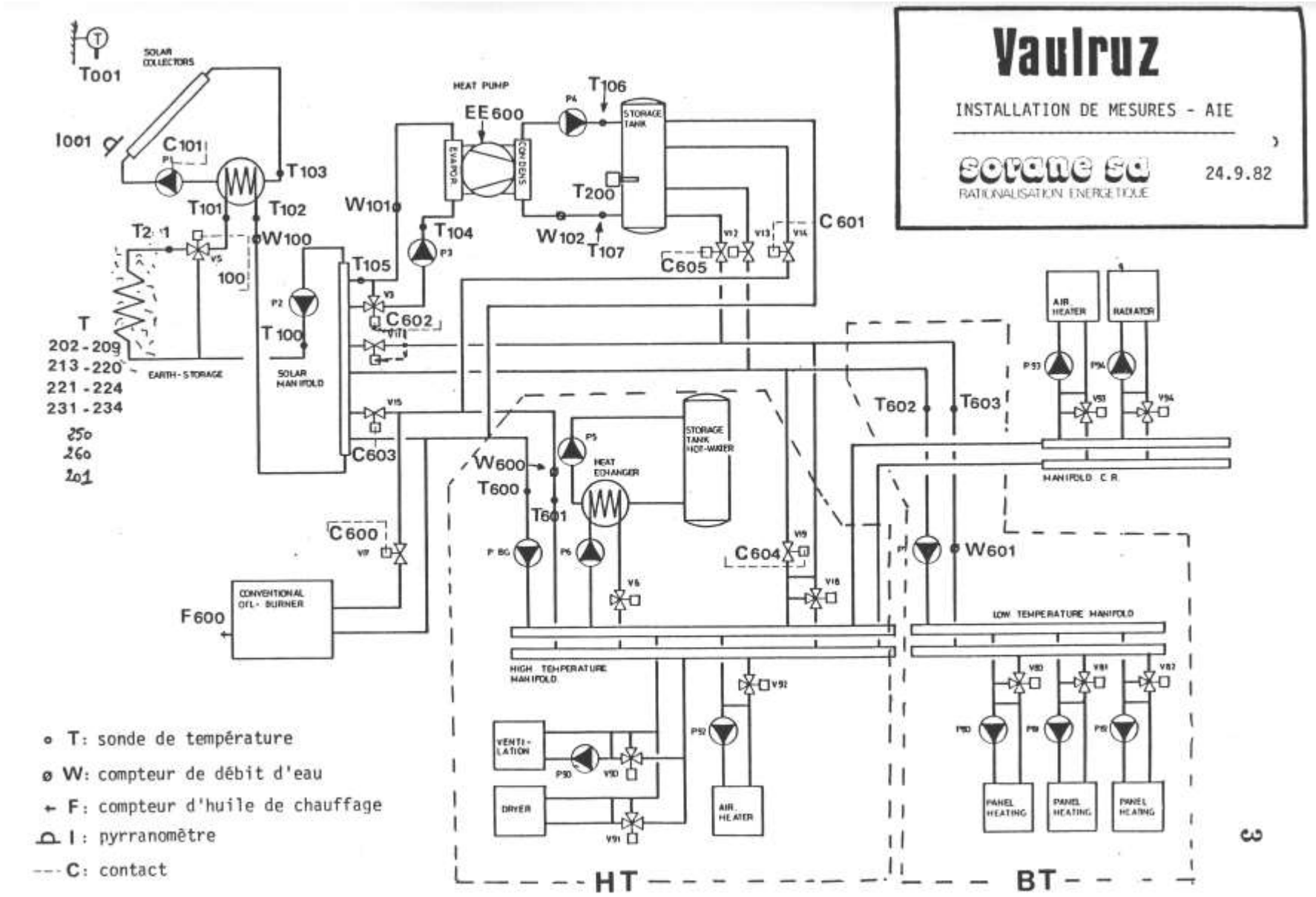


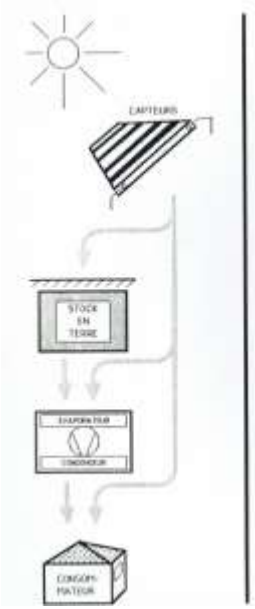
Figure 1 : Points de mesures dans l'installation

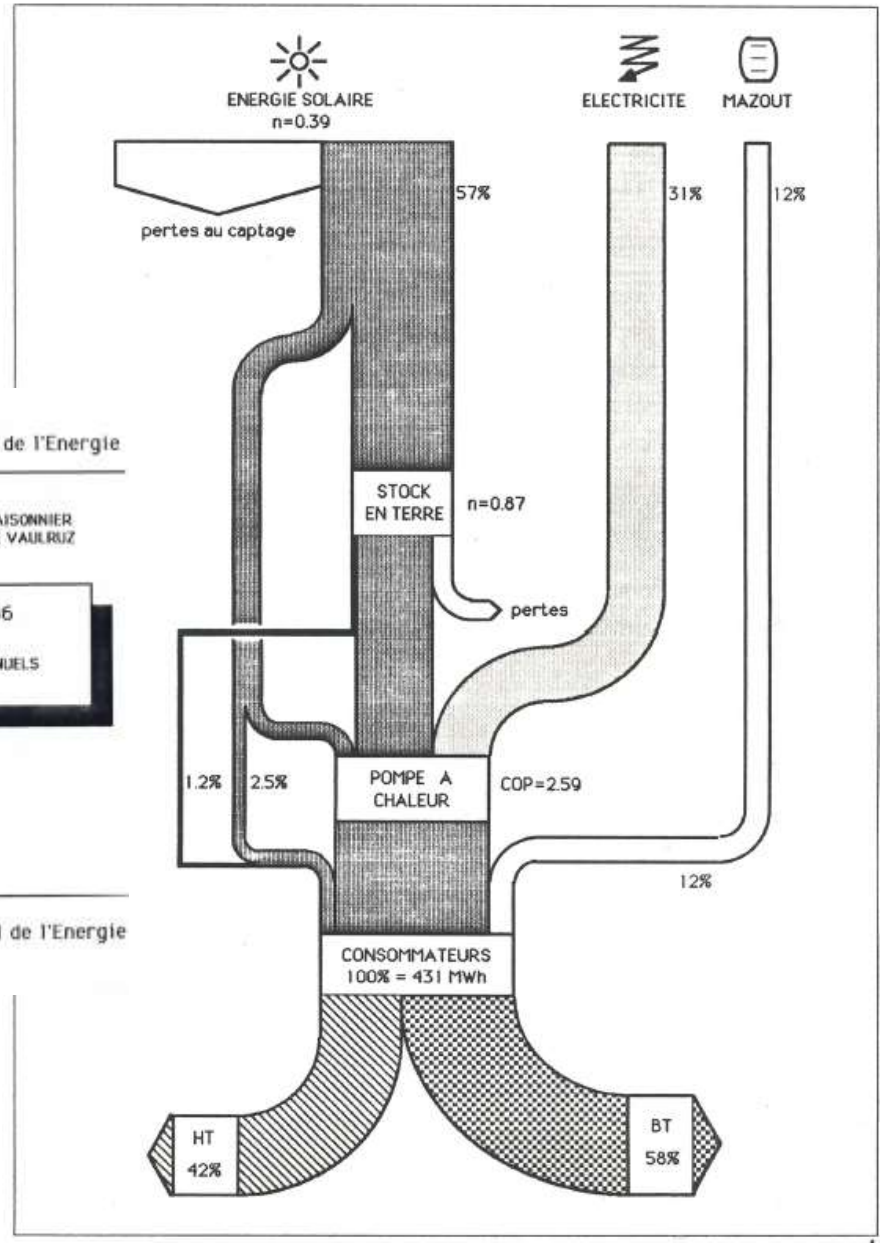
Project performed partly by P. Jaboyedoff when employed by Sorane

Effin'Art
The Art of Energy Efficiency

IEA VII SHC Central Solar Heating Plants with Seasonal Storage (CSHPSS)

- Vaulruz
  - 1986 measured results
  - Later new heat pump
    - COP from ~2.5 → 5
  - Storage used for a validation exercise with DST (no graphical representation available (archives))





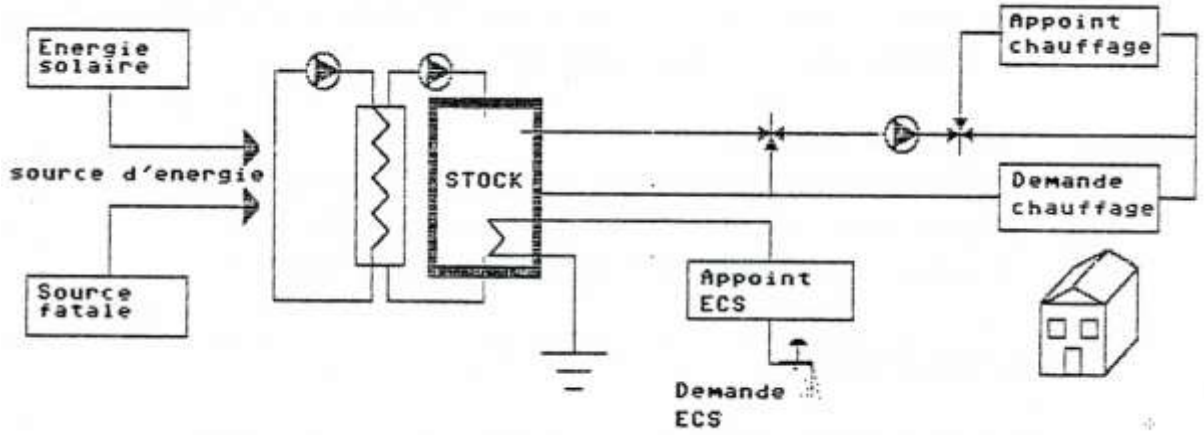
Project performed partly by P. Jaboyedoff when employed by Sorane

1989	3rd Workshop on Solar Assisted Heat Pumps with Ground Coupled Storage	Göteborg, Sweden	13.-14. January 1989

Effin'Art
The Art of Energy Efficiency

IEA VII

- Seasonal storage
- Simplified simulation model
  - 10 days time steps



Project performed by P. Jaboyedoff when employed by Sorane


Office fédéral de l'énergie
Bundesamt für Energiewirtschaft
OFEN
BEW

Le stockage saisonnier de chaleur et sa possibilité d'application en Suisse

Séminaire organisé par l'OFEN.

Berne, **7 juin 1985**

Fachtagung organisiert vom BEW.

Bern, **7. Juni 1985**

Die saisonale Wärmespeicherung und ihre Anwendungsmöglichkeiten in der Schweiz

Effin'Art
The Art of Energy Efficiency

SICPA (acronym for Société Industrielle et Commerciale de Produits Alimentaires) is a Swiss company that is the worldwide leader of security inks for currencies and sensitive documents,[2] including identity documents, passports, transport and lottery tickets

- Process cooling by water from the river → change of law
- Cooling has to be performed with ambient cooling (either chiller or other mean)
- Study of direct cooling with a cooling tower avoiding chillers
- Audit on site, Characterisation of the process with time constraints
- Dynamique simulation with TRNSYS 13, parametric analysis and sizing of cooling tower (no graphical interface then)
- Parametric study
  - Results and actual implementation:
    - No cooling maching
    - Cooling by cooling tower
    - Anecdote:
      - When we asking the HVAC consulting company about over sizing margin they had considered they said 0% !
      - So it worked as simulated

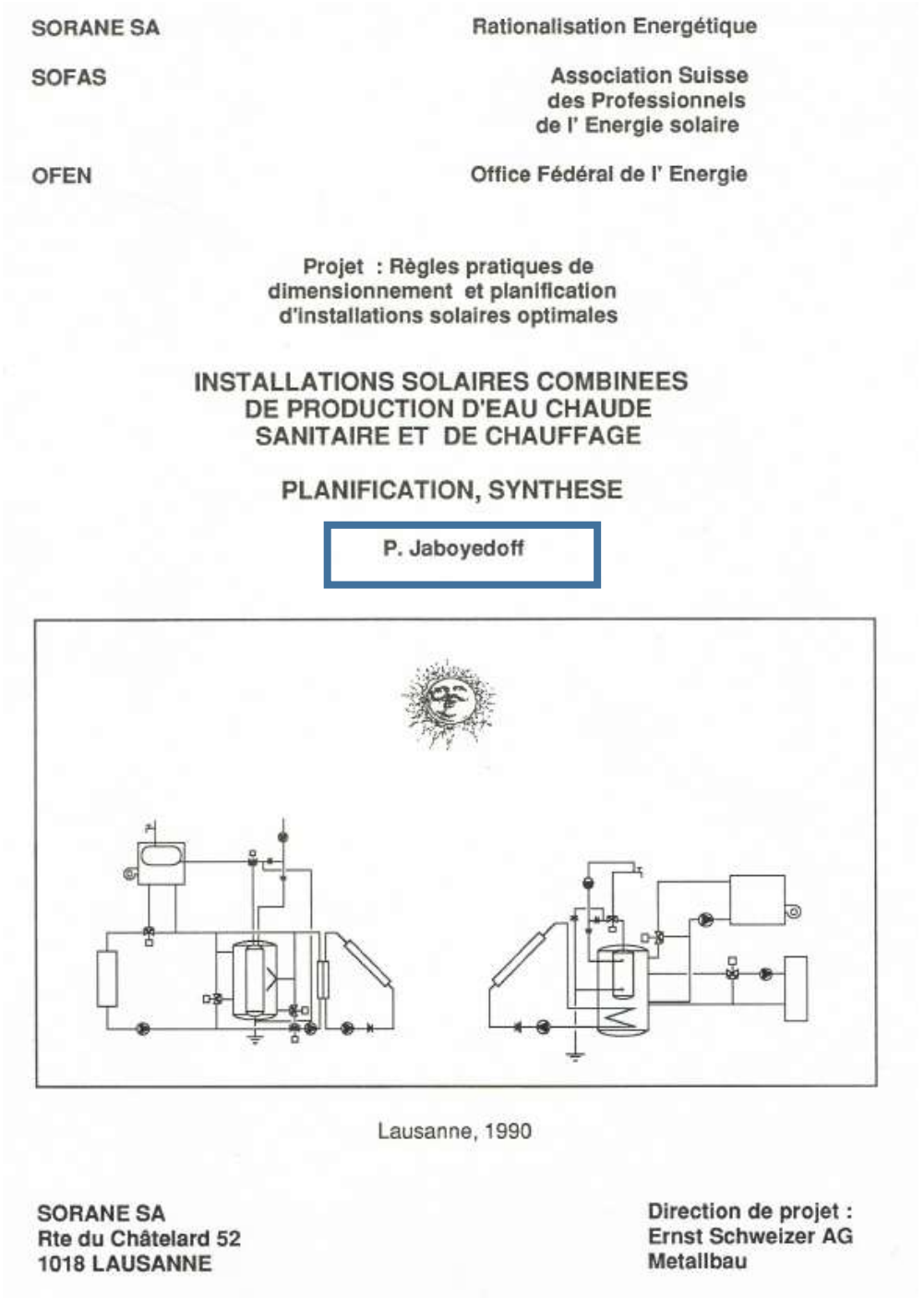
Project performed by PJ when employed by Sorane

Effin'Art
The Art of Energy Efficiency

SOFAS (1987-1992)

Association suisse des professionnels de l'énergie solaire

- Development of specific TRNSYS models for two installation measured with great detail at 5 minutes time steps
- Validation against measurment
- Development of guidelines for the design of solar installation for space heating and domestic hot water for the SOFAS



SORANE SA — Rationalisation Energétique

SOFAS — Association Suisse des Professionnels de l' Energie solaire

OFEN — Office Fédéral de l' Energie

Projet : Règles pratiques de dimensionnement et planification d'installations solaires optimales

INSTALLATIONS SOLAIRES COMBINEES DE PRODUCTION D'EAU CHAUDE SANITAIRE ET DE CHAUFFAGE

PLANIFICATION, SYNTHESE

P. Jaboyedoff

Lausanne, 1990

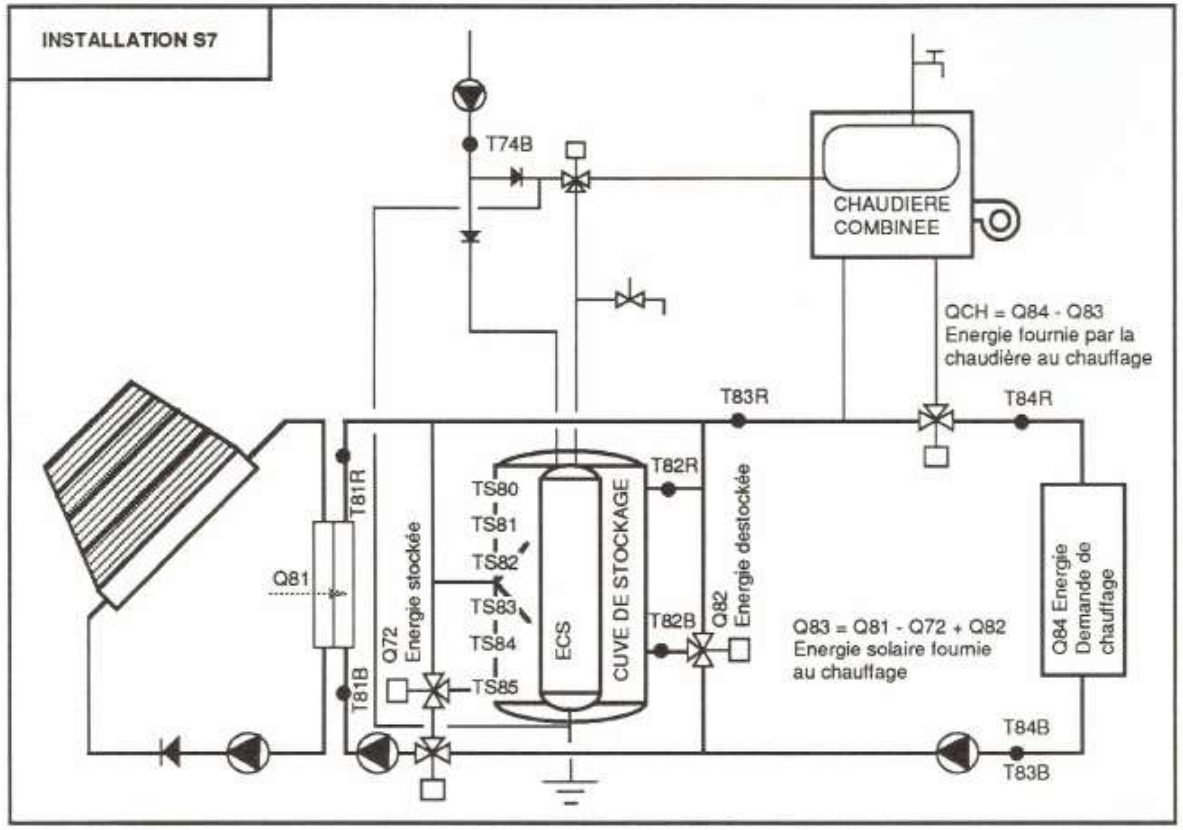
SORANE SA
Rte du Châtelard 52
1018 LAUSANNE

Direction de projet :
Ernst Schweizer AG
Metallbau

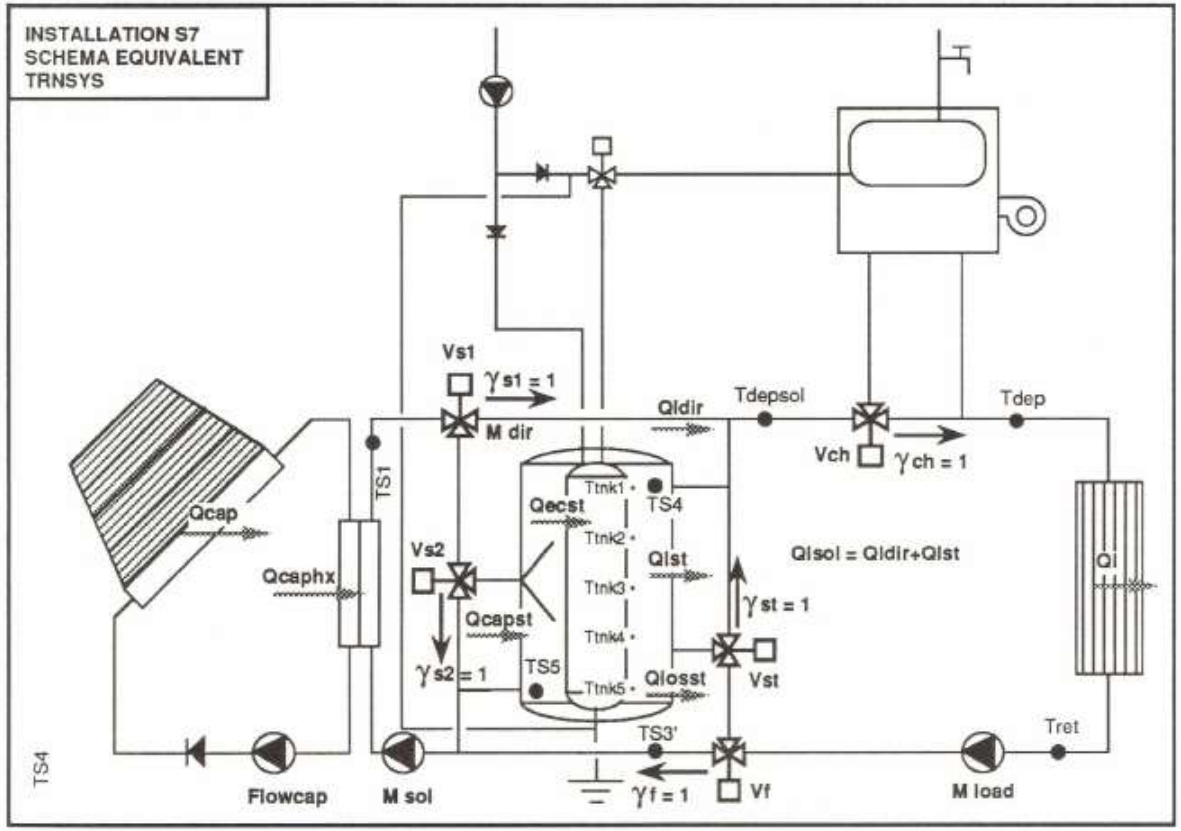
Effin'Art
The Art of Energy Efficiency

SOFAS

- Installation with «direct injection»
- Schematic description

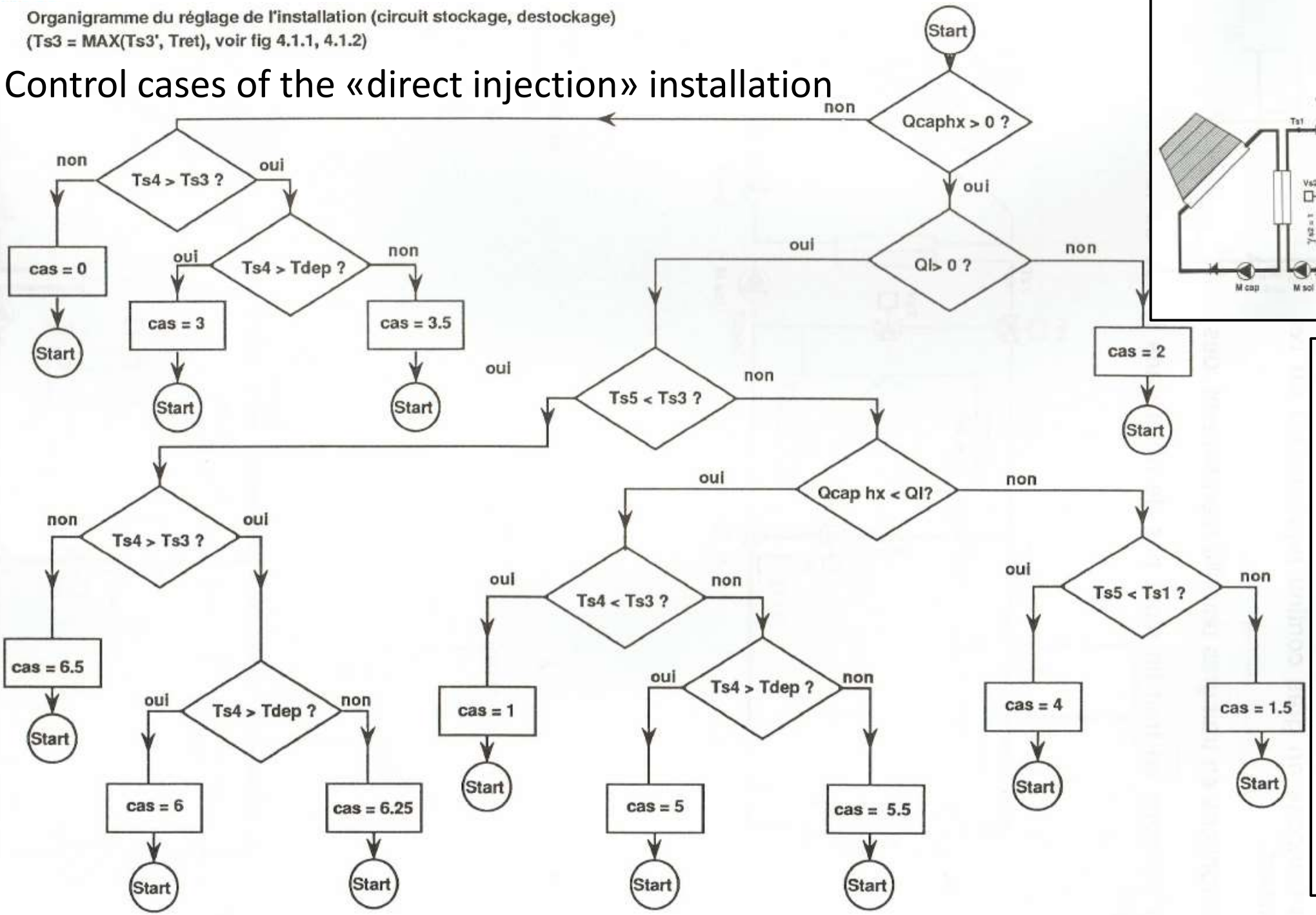


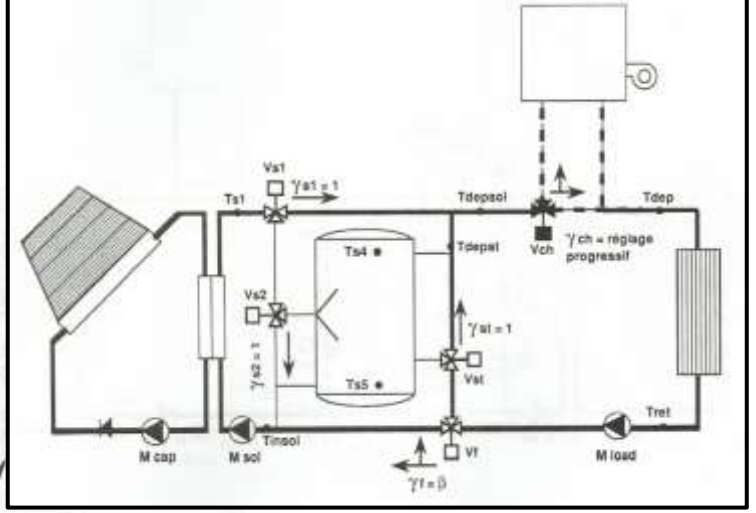
Equivalent schema for TRNSYS



Control cases of the «direct injection» installation

Organigramme du réglage de l'installation (circuit stockage, destockage)
(Ts3 = MAX(Ts3', Tret), voir fig 4.1.1, 4.1.2)



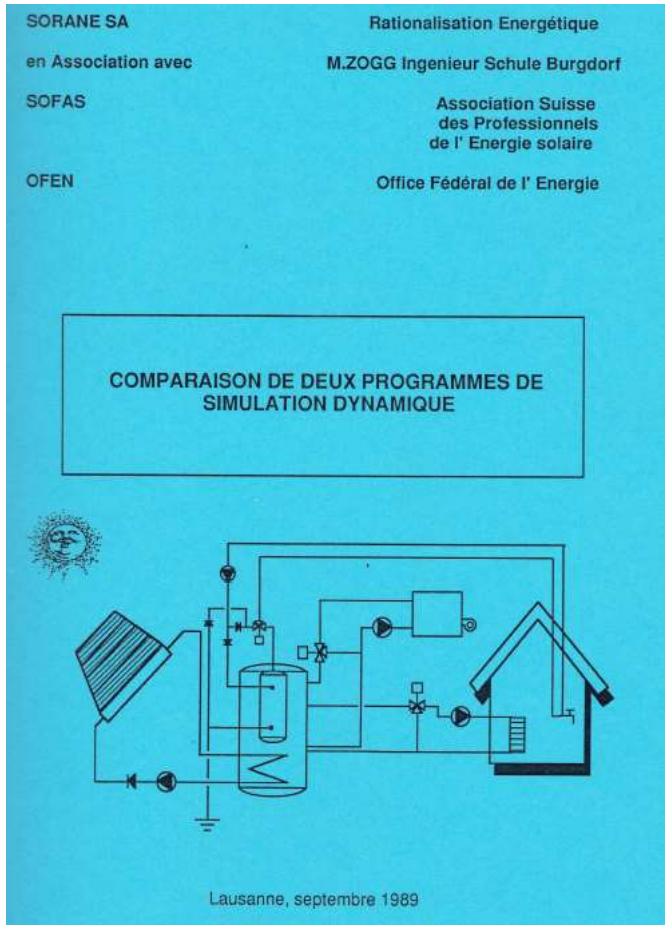


- Development of a control module for TRNSYS
  - Modification of the kernel of TRNSYS to control (in Exec.for,
    - Correct convergence of case (**icaschk**)
    - Reiterate if not (Reiter flag)
    - Give the OK for the next time step (if Reiter=-1)

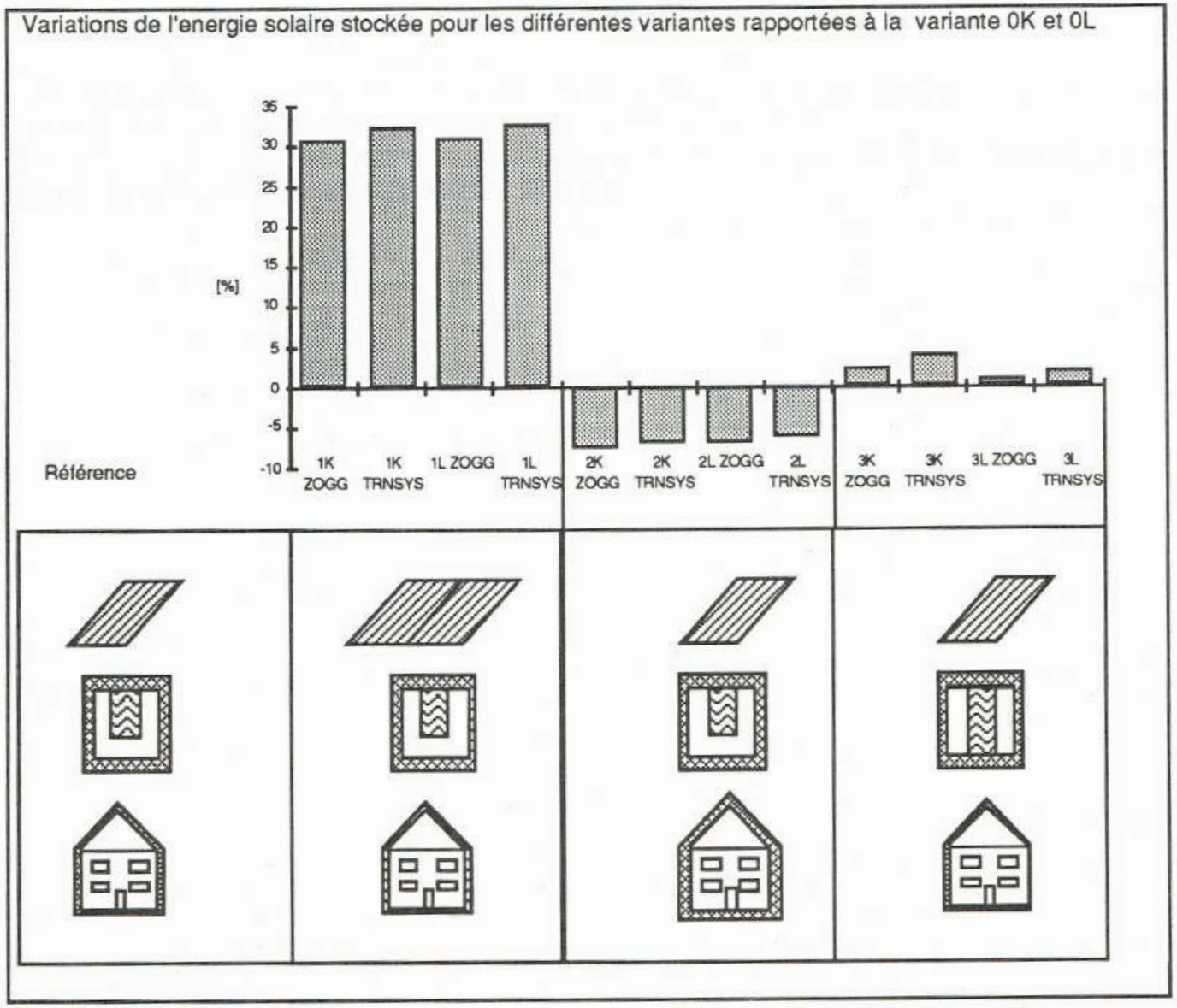
Effin'Art
The Art of Energy Efficiency

SOFAS

- Intermodel (TRNSYS – SIWWH) comparison
- After end of the project



La figure 2.2 présente les variations de l'énergie solaire stockée par rapport au cas de référence pour Kloten (K) et Locarno (L) pour les trois variantes.



Project performed by PJ when employed by Sorane

Effin'Art
The Art of Energy Efficiency

SOFAS conclusions

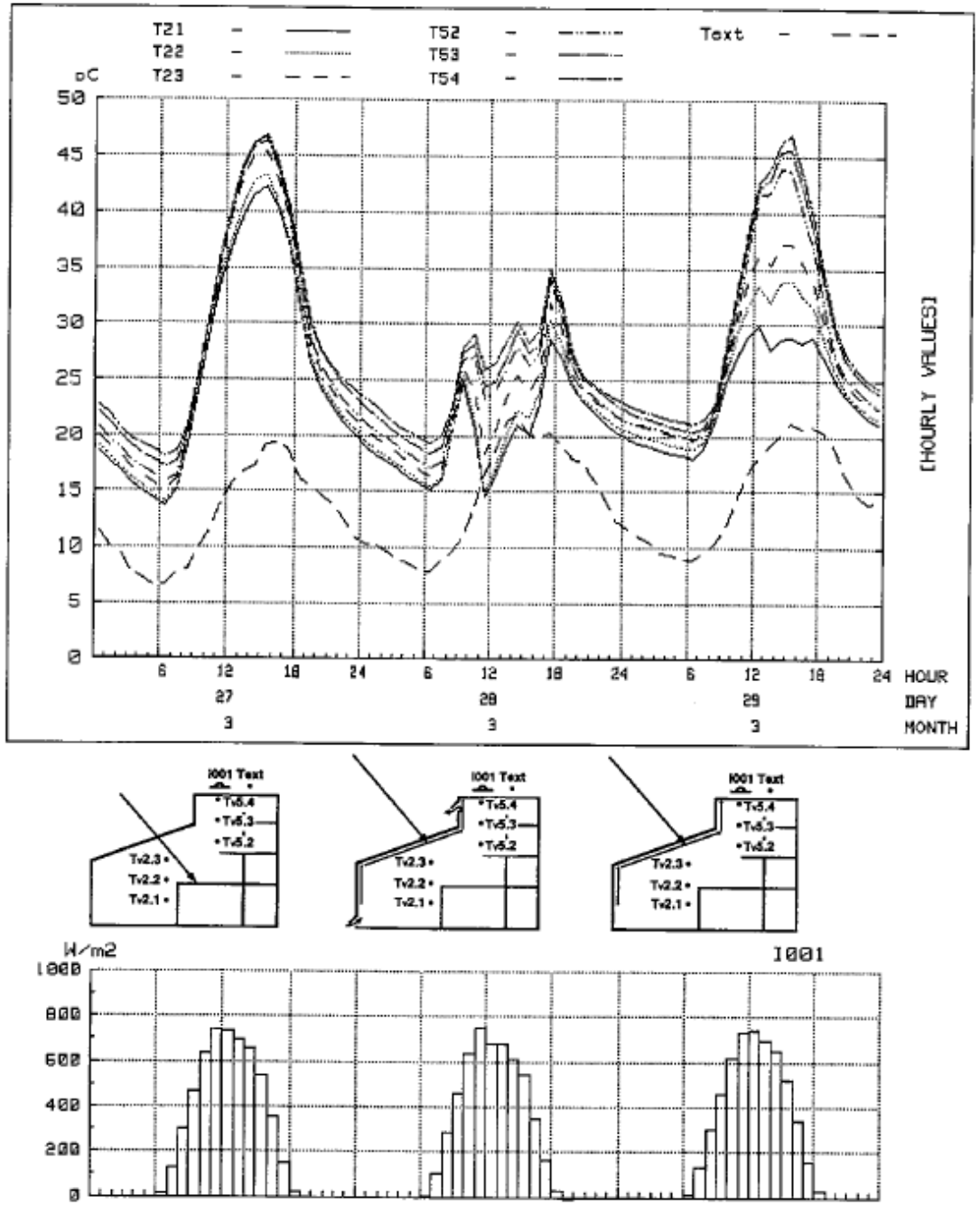
- The validation allowed to develop simple design rules for practice (issued by the SOFAS, the professional association of solar collectors and installations manufacturers)
- The sophistication can only be assessed by detailed dynamic simulation
- Leaks in one valve on the real measured installation was found by simulation during the validation exercise
- Direct use of the «control» module applicable with simple modifications to other type of installations (used later for the GEOSER project)
- An Intermodel (TRNSYS – SIWWH) comparison was performed and gave a high level of confidence for the users of the two simulation programs → the program SIWWH was later further developed and was the base for the specific program POLYSUN

Project performed by PJ when employed by Sorane

Effin'Art
The Art of Energy Efficiency

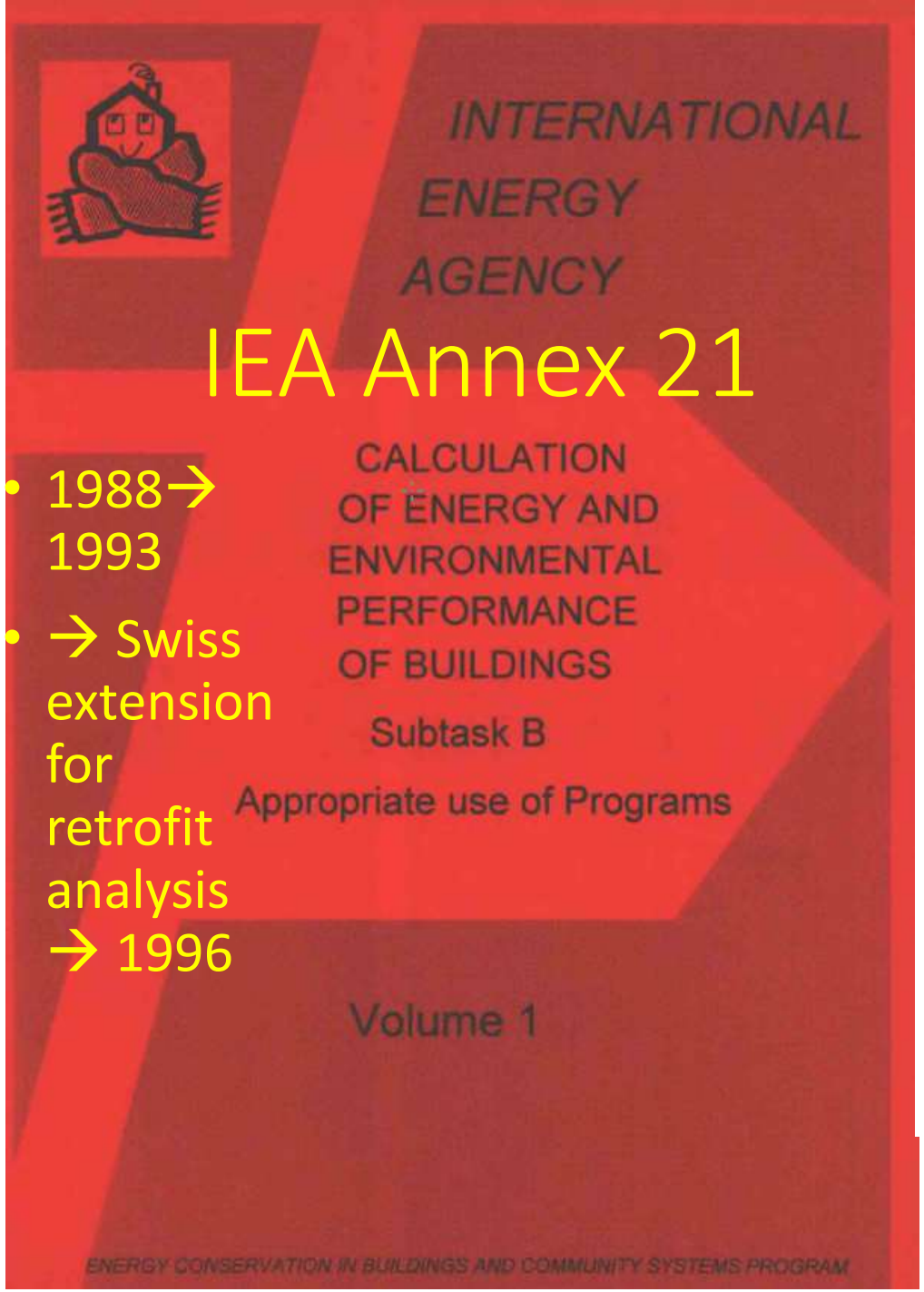
IEA-SHC Task 11 NUNI Atrium

- Case study with measurement of the stratification as a function of
  - Shading on/off
  - Vents closed/open
  - Served as a basis for further study in Task 12
- Measuring campaign allowed to validate the design concept (shading, temperature stratification)



Project performed partly by PJ when employed by Sorane

Effin'Art
The Art of Energy Efficiency



- 1988→ 1993
- → Swiss extension for retrofit analysis → 1996

Appendix 1 Contributors

Country	Name and organisation
Australia	**A. Delsante;** CSIRO
Denmark	**K. Johnsen;** SBI, Hörsholm
Belgium	**P. Verstraete, R v d Perre, T v Doninck;** Vrije Univ., Brussels
Finland	**T. Kalema, T. Haapala, S. Kataja;** Tampere Tech. Univ.
France	**P. Dalicieux;** Electricité de France
Italy	V. **Bocchio, A. Mazza;** Politecnico di Torino
The Netherlands	**A. Wijsman;** TNO-Bouw, Delft
Switzerland	**G. Zweifel;** EMPA, **Dübendorff, P. Jaboyedoff, C. Prudhomme;** Sorane SA, Lausanne. **A. Duppenthaler;** Byron, Basle
Spain	**E. Rodriguez;** Escuela Sup. Ing. Ind. Seville
Great Britain	**D. Bloomfield** (project leader), **F. Parand, L.P. Roche, S. Hammond;** BRE. **M. Gough, A. Jones;** EDSL; **K. Lomas, P. Moors, H. Eppel;** De Montford Univ., Leicester. **J. Wiltshire, B. Warren, B. Sodagar;** Univ. Newcastle. **M. Holmes;** Arup & Partners. **P. Strachan;** ESRU Univ. of Strathclyde, Glasgow. **G. Stuart;** ASL. **A. Tindale, S. Irving;** Facet Ltd. **D. Alexander,** Univ. of Wales, Cardiff
Sweden	**M. Wall, P. Wallentén;** Byggnadskonstr.lära, LTH, Lund
Germany	**U. Willan;** Rudolf Otto Meyer (ROM). **C. Hertkorn;** IFIB Univ. Karlsruhe, **W. Hartmann;** Ebert, Munich. **P. Pfrommer;** FHT Stuttgart
USA	**M. Holtz** (project leader); Arch Energy Corp, Boulder CO, **R. Judkoff;** NREL, Boulder CO, **M. Brambley;** PNL, Richland, WA. **M. Kennedy;** Ecotope. **B. Miller, D. Hittle;** Colorado State Univ. **J. Thornton;** Univ. Wisconsin. **F. Winkelmann;** LBL, Berkeley

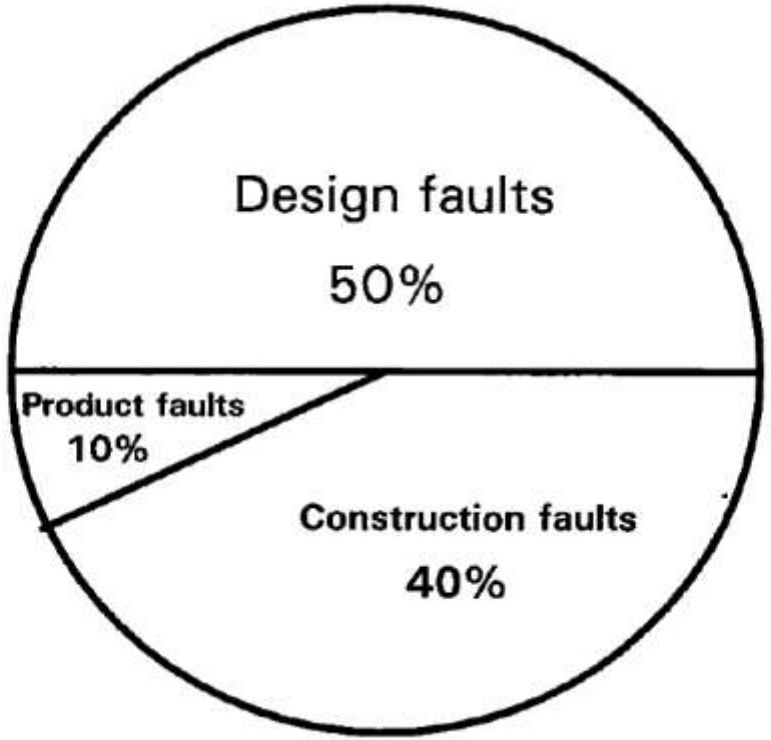
Project performed by PJ when employed by Sorane in collaboration with EMPA

Effin'Art
The Art of Energy Efficiency

- As per BRE studies, 90% of building failures (in term of energy performance) are due to design and construction faults

2.1 Introduction: Need for Quality Assurance

Reports published by BRE and other bodies have conclusively demonstrated that 90% of all building failures have their origin in faults in design and construction (design faults being responsible for 50% of all failures), Fig. 2.1, [1, PSA, 1986].



Effin'Art
The Art of Energy Efficiency

IEA Annex 21, appropriate use of Programs, TRNSYS

4.4.3 Ventilation; Investigation summary
P. Jaboyedoff, C. Prudhomme

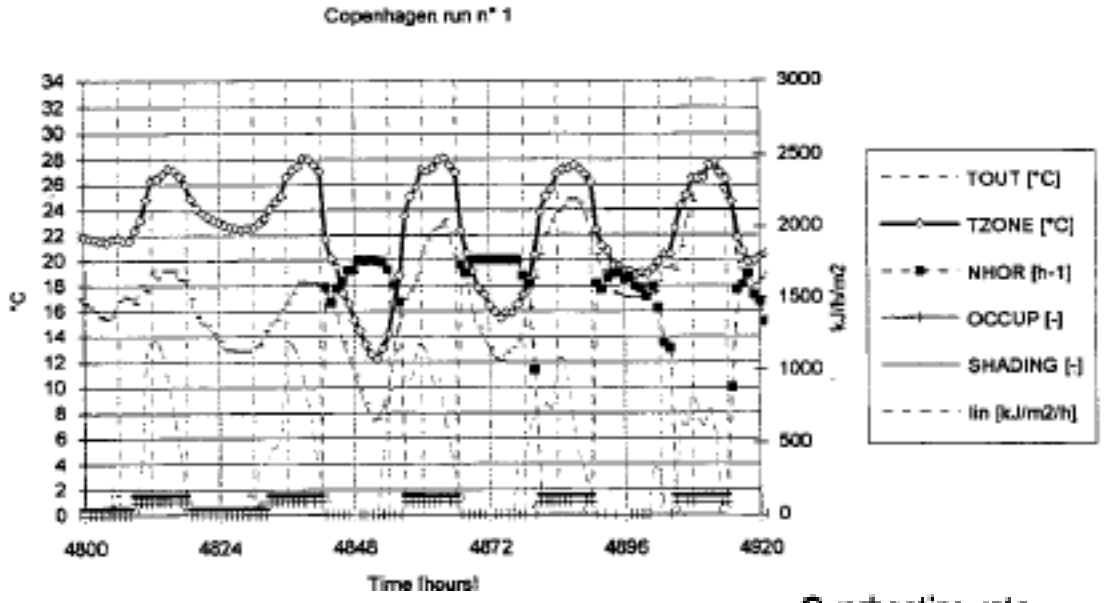
As an example of the impact of assumptions made by users when using simulation tools, two different simulations of building office modules located at Copenhagen are presented in Table 4.1(see Copenhagen run n°1 and Copenhagen run n°3).
The differences in the assumptions are:

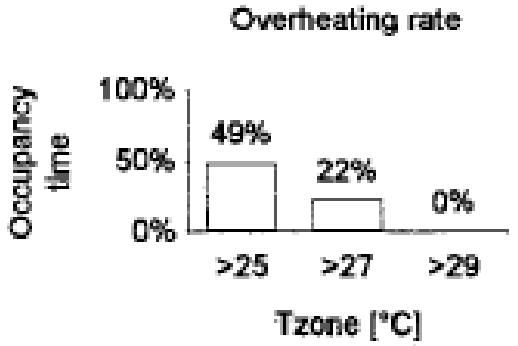
	Run 1	Run 3
Run conditions		
(see explanations on table 4.2)		
Opening strategy (MODE)	3	4
Opening operation	2	2
Calculation of airchange (N)	2	2
Min temp. for night opening	26	every night
N airchange as input	-	-
Max air change rate	20	20
Blind shading coeff.	0.5	0.5
Window shading coeff.	0.87	0.87
Min solar rad for blinds	360	360
Discharge coeff. day time	0.6	0.6
Discharge coeff. night time	0.25	0.25
Attenuation by blinds [%]	30	30

Table 4.1

7.6 Application In Practice

A computerised system has been developed in Switzerland to allow linking of the program manual and the documented PAM together with an editor that enables the production of input data files for the program. This on-line Help facility has hypertext features and promises to substantially improve the efficiency and quality of modelling.

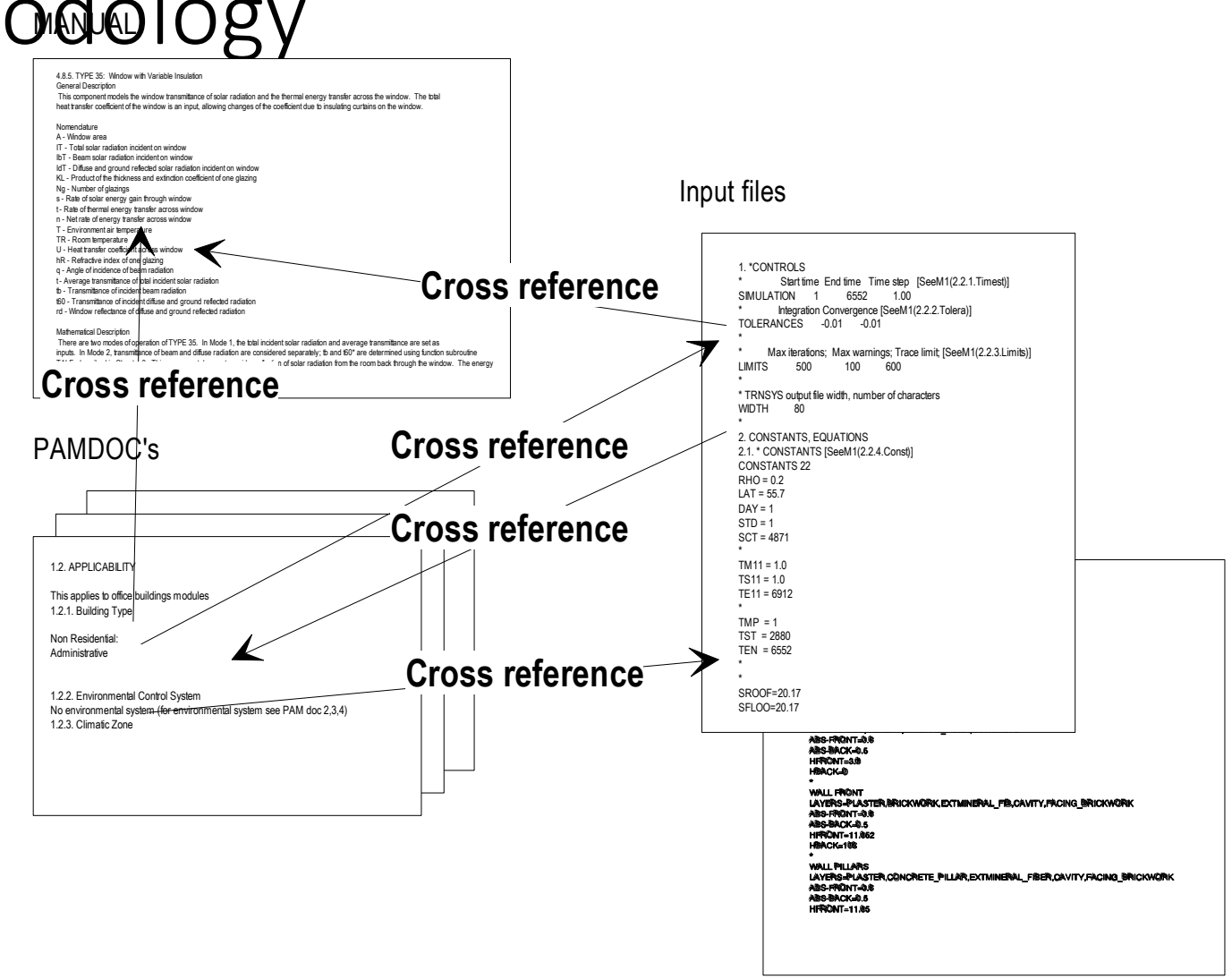




Effin'Art
The Art of Energy Efficiency

IEA 21 interactive documentation for TRNSYS 13.1 Overheating risk methodology

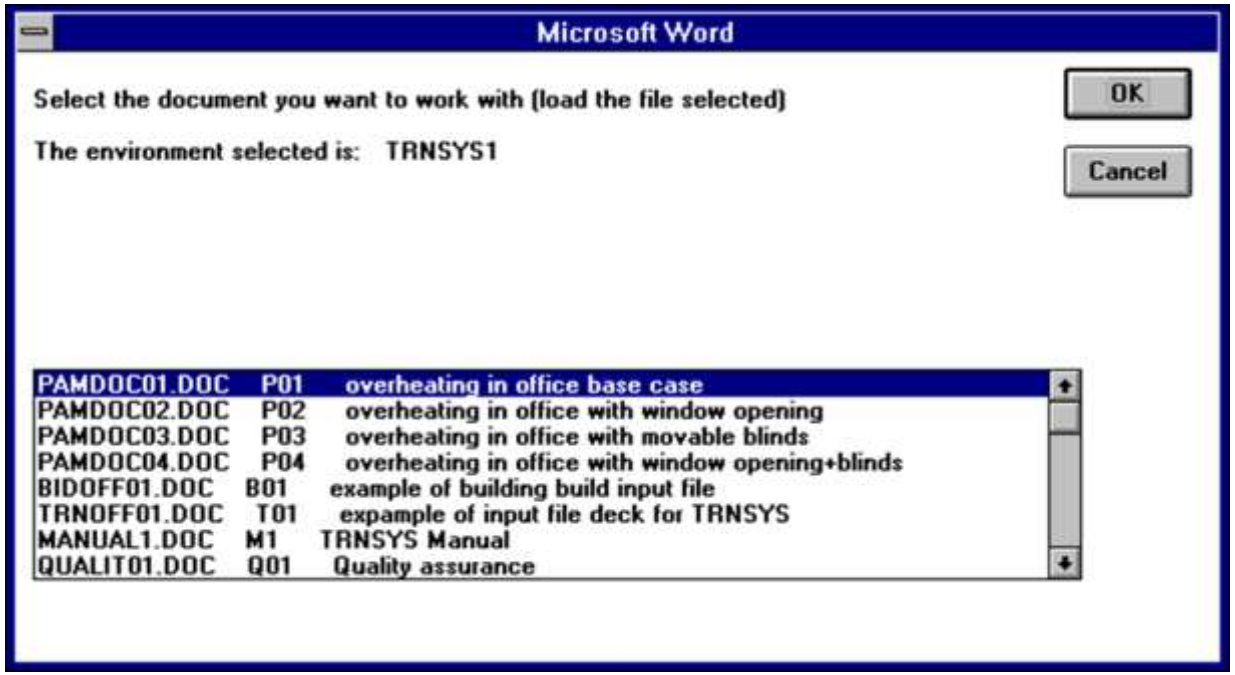
- Got the raw manual from TRNSYS Wisconsin
- Developed (1992-93) before **HTML** and **php** in word 2.0 basic macro language interactive structured documentation creation of links between
  - TRNSYS Manual
  - Performance Assessment Method Documentation (PAMDOC's)
  - Input files
    - System (.dck)
    - Building (.bid)
- Became useless when internet became mainstream (html, php etc…) ☹ → be careful with rapid technology changes !!, before investing time in a software development, check the sustainability.

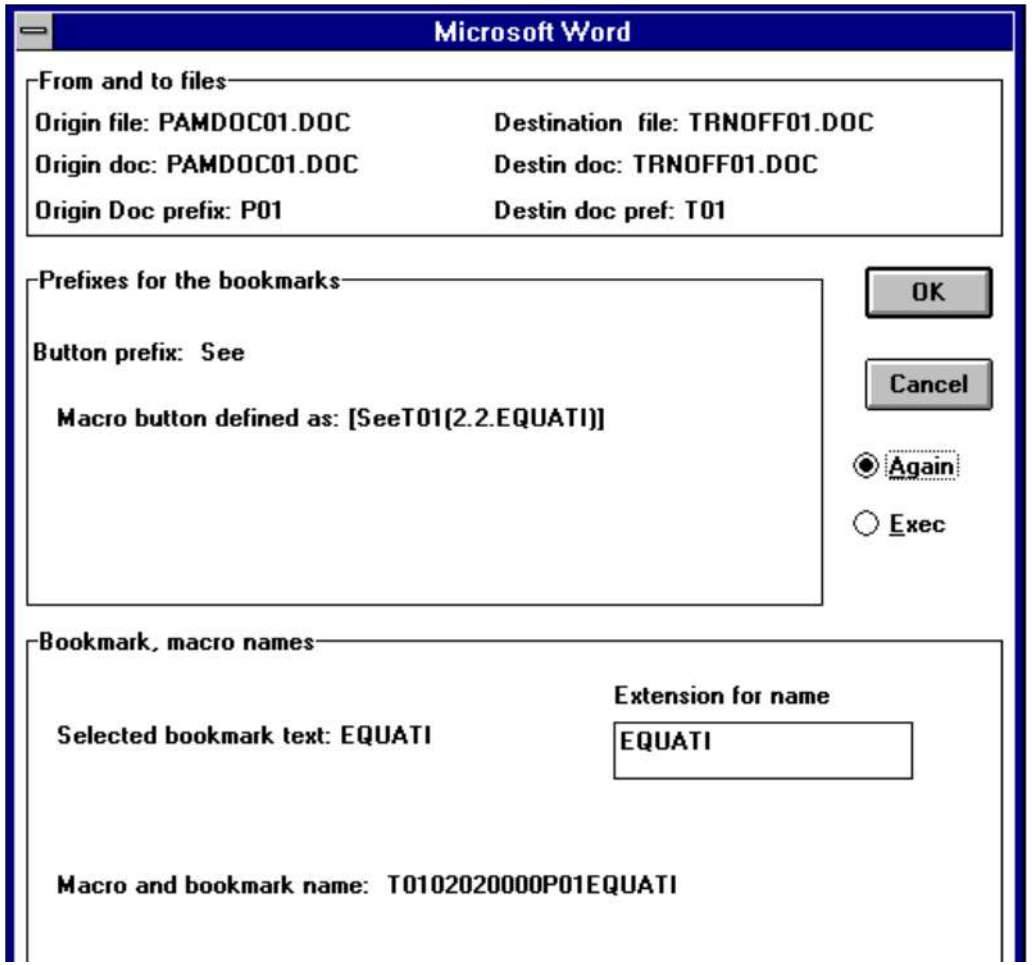


Effin'Art
The Art of Energy Efficiency

IEA 21 Subask B, appropriate use of programs, Dynlink (generator of interactive links in Word 2.0)

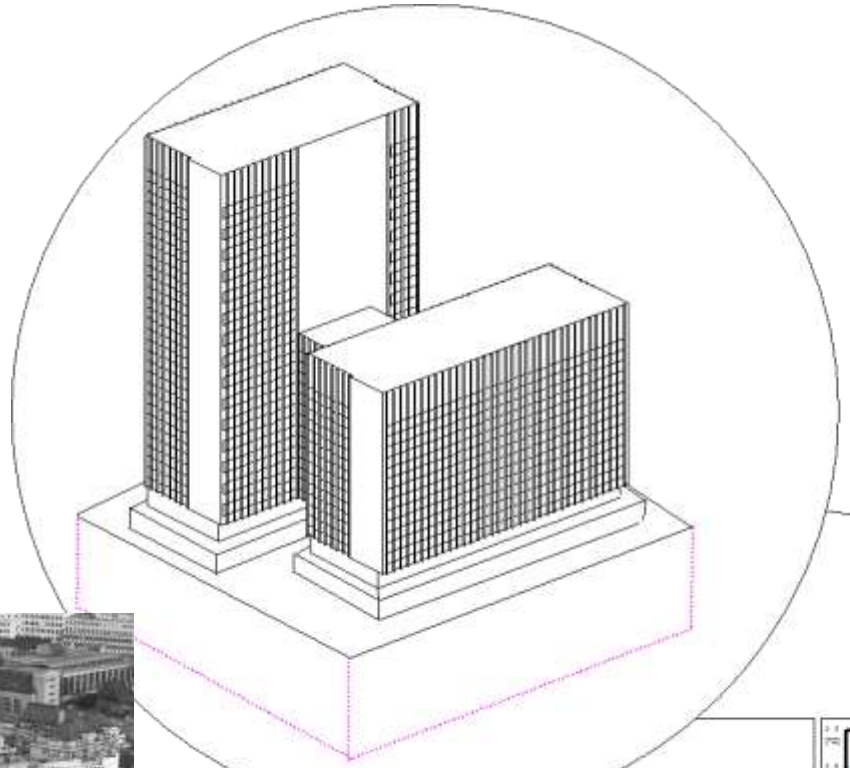
- Development work which became waste couple of years later ☹ → be careful with rapid technology changes !!

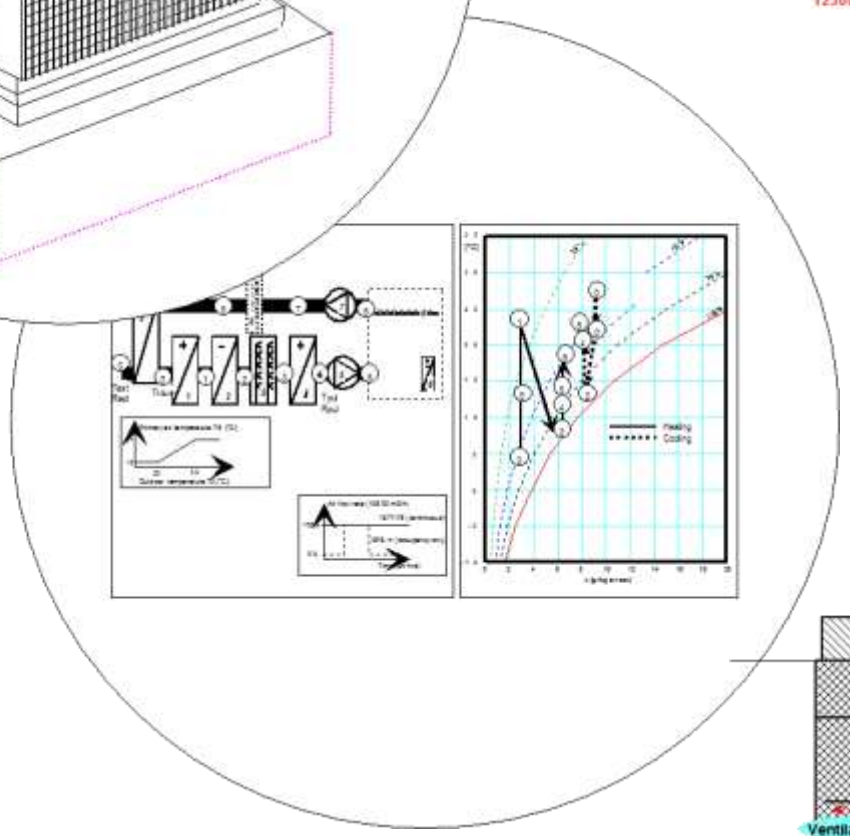


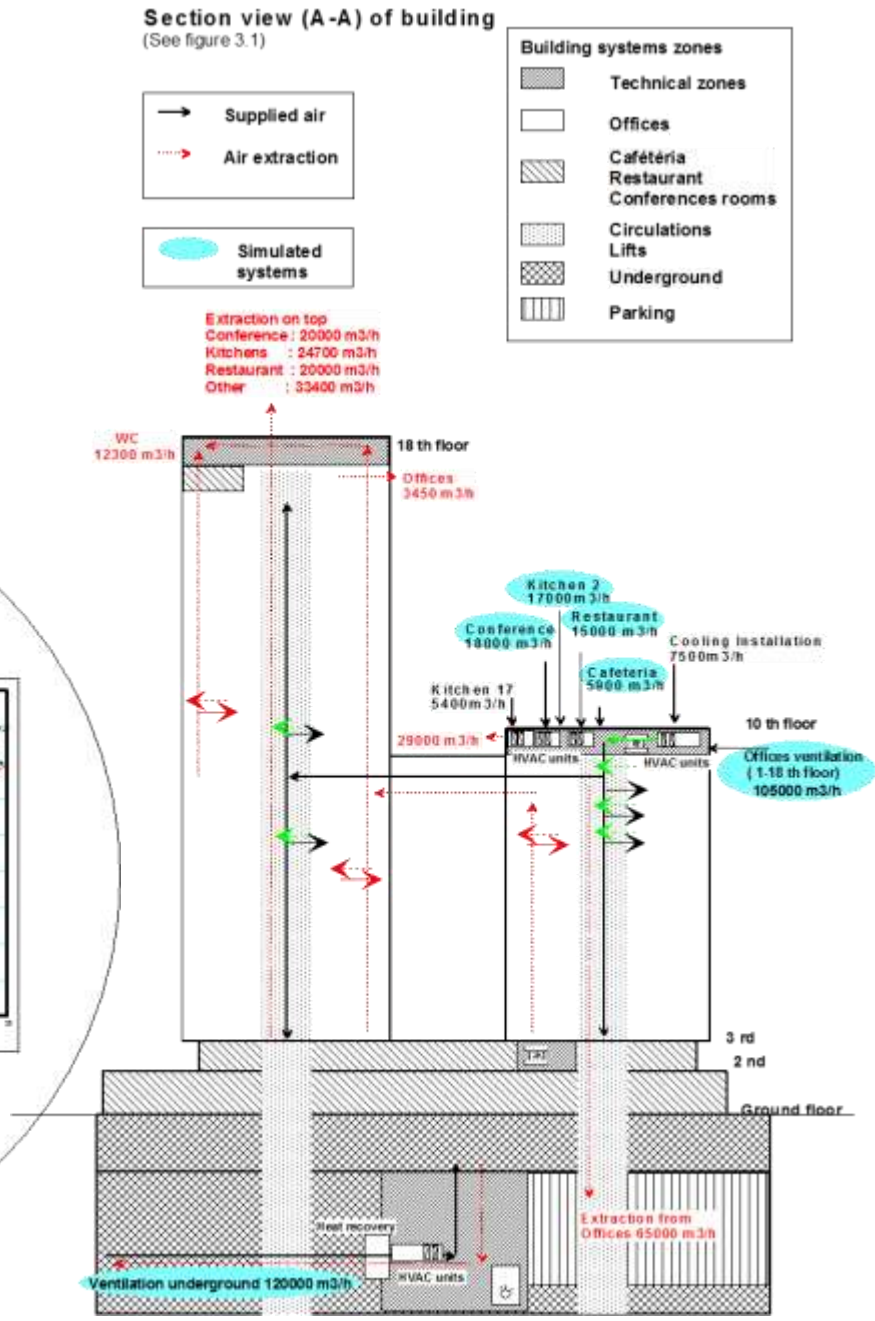


Effin'Art
The Art of Energy Efficiency

IEA 21 retrofit case study





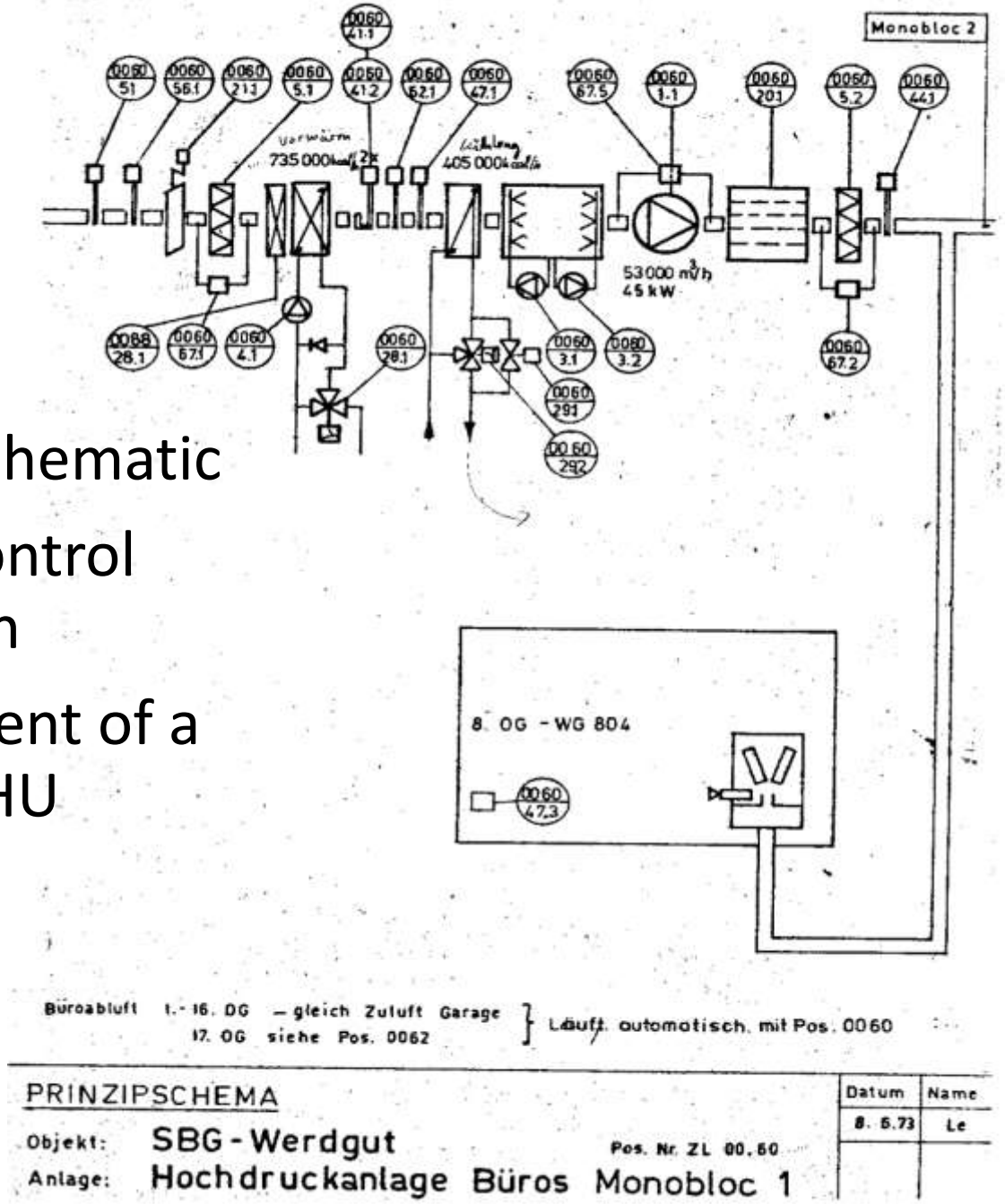


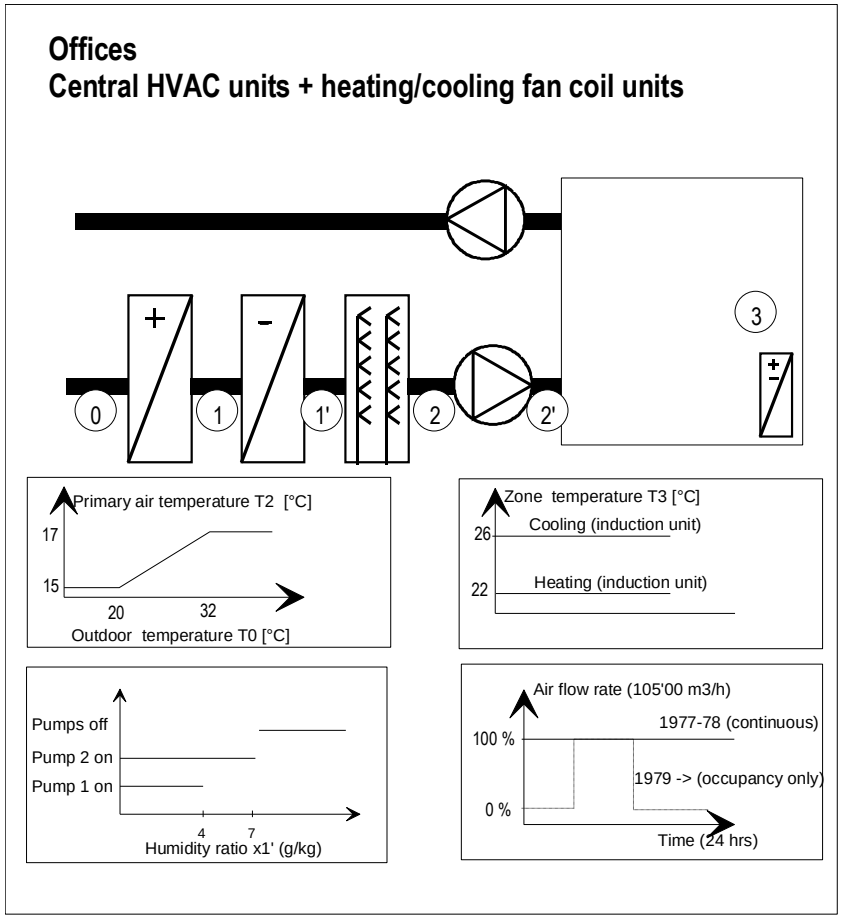
Work performed under the responsibility of P. Jaboyedoff when employed by Sorane

Effin'Art
The Art of Energy Efficiency

IEA 21 AHU Model development

- Original Schematic
- Original control description
- Development of a TRNSYS AHU routine

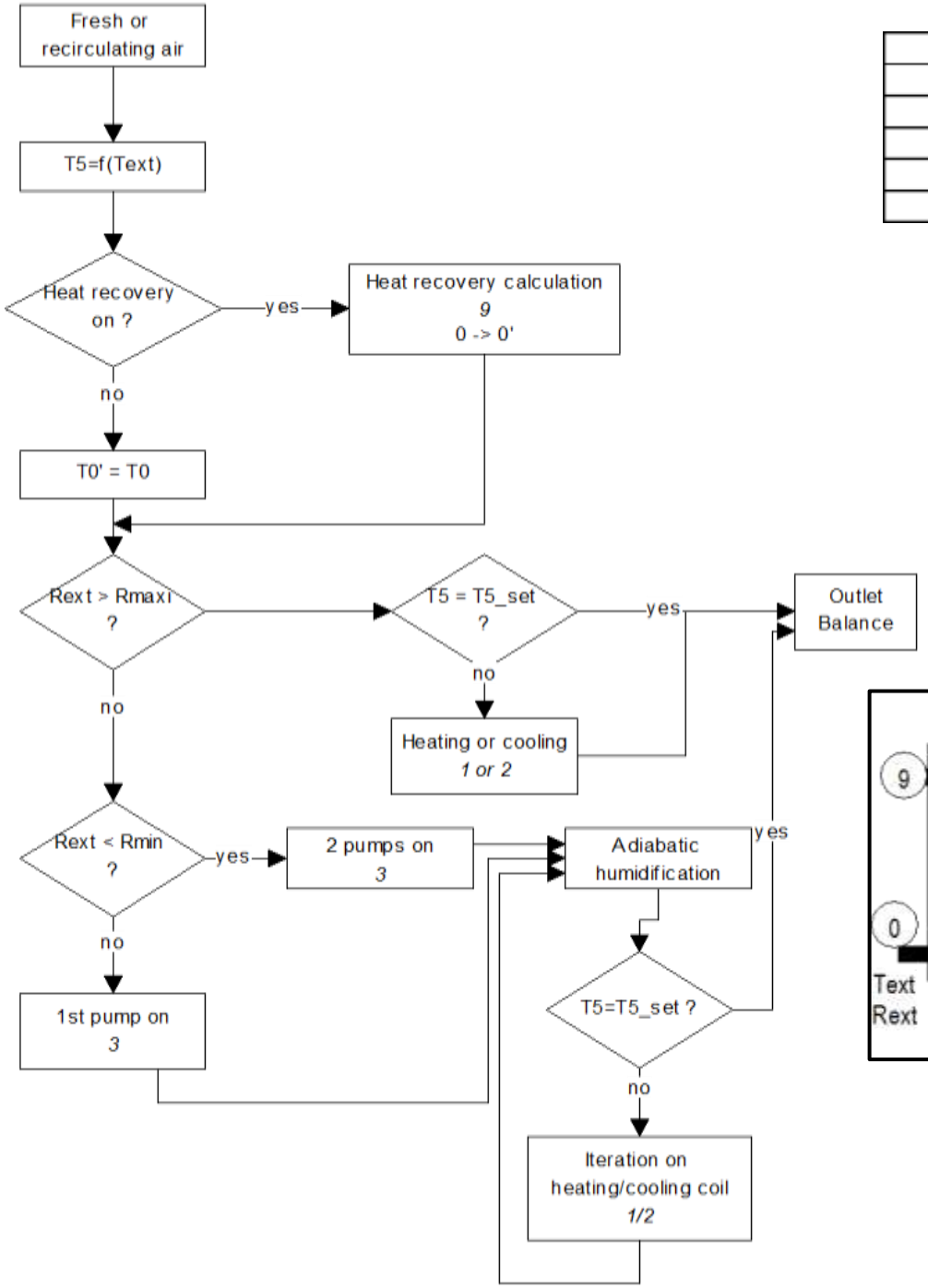




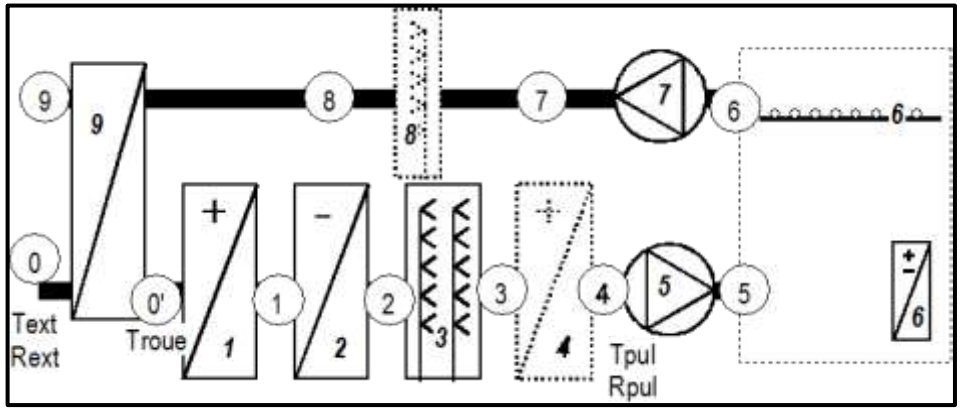
Effin'Art
The Art of Energy Efficiency

IEA 21 Absolute humidity model

- TRNSYS AHU model developed
- In 1993, no AHU model available for TRNSYS

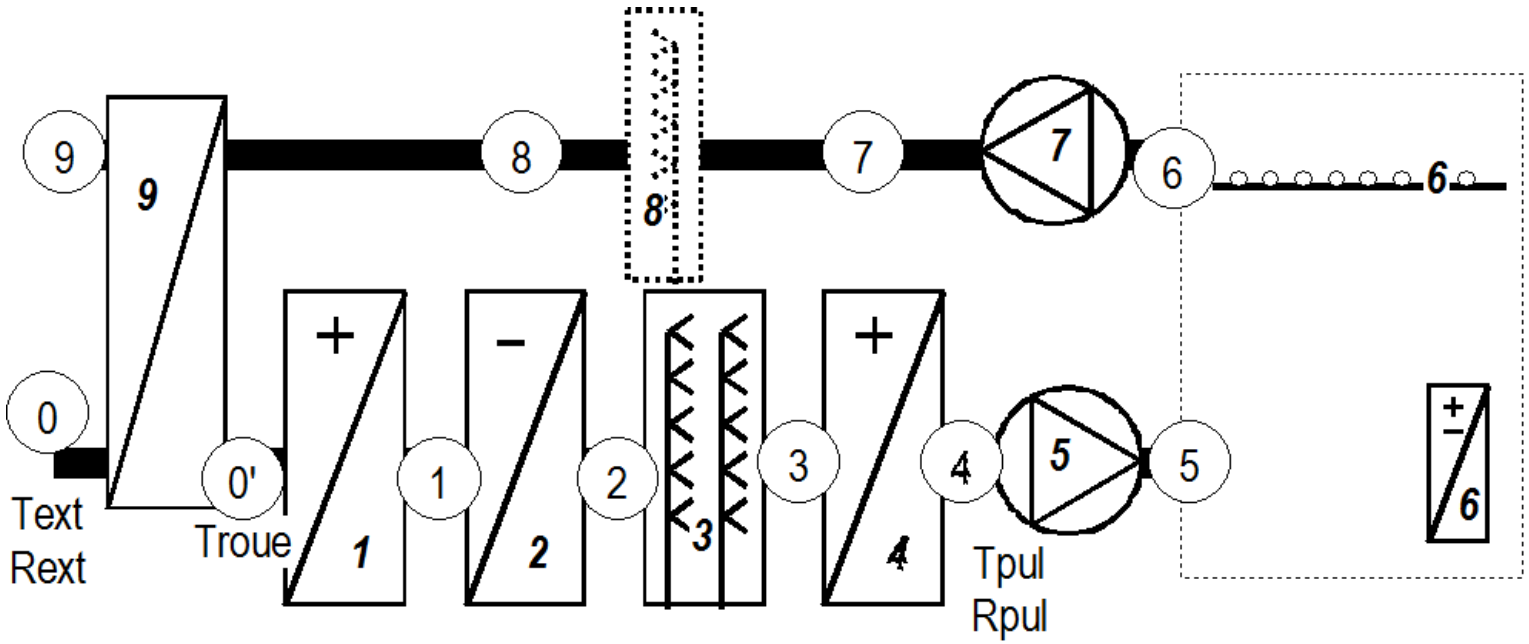


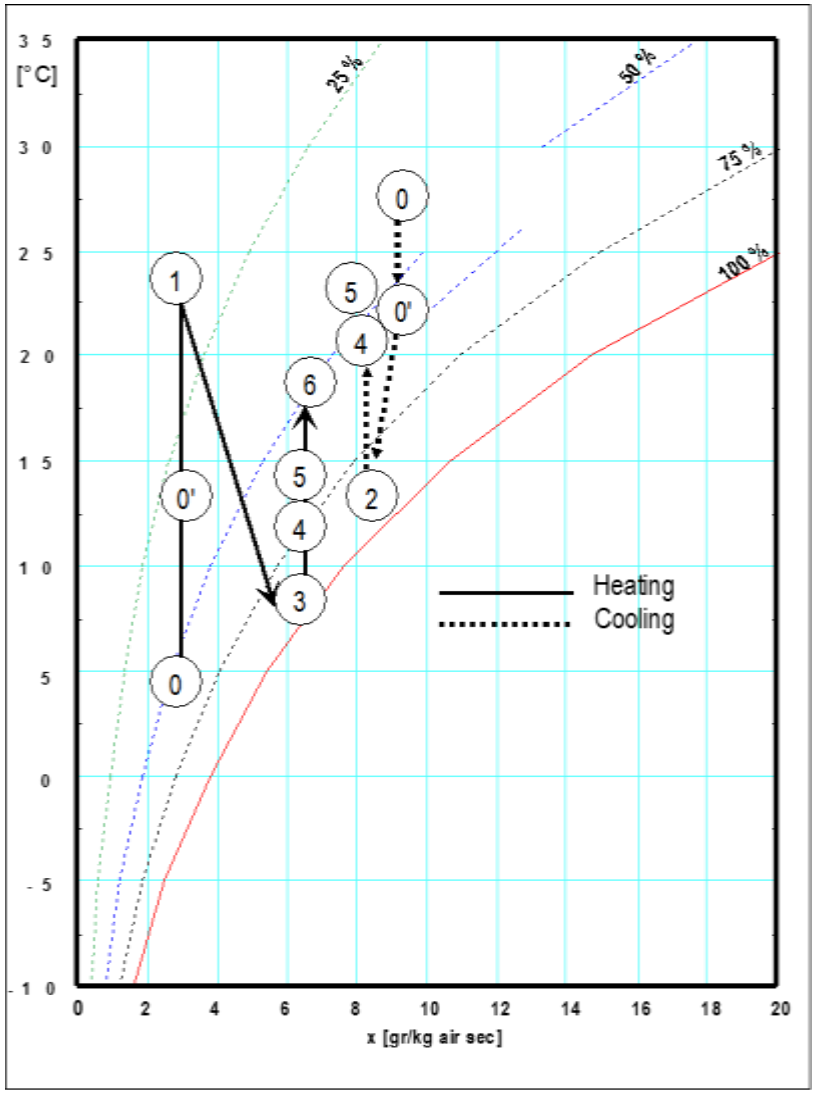
	System arrangement	Heat recovery
1	Humidity control based on ambient humidity	x
2	Dew point control	x
3	Variable flow rate	x
4	Adiabatic cooling	x
5	Adiabatic cooling and variable flow rate	x



Effin'Art
The Art of Energy Efficiency

IEA 21 Dew point model

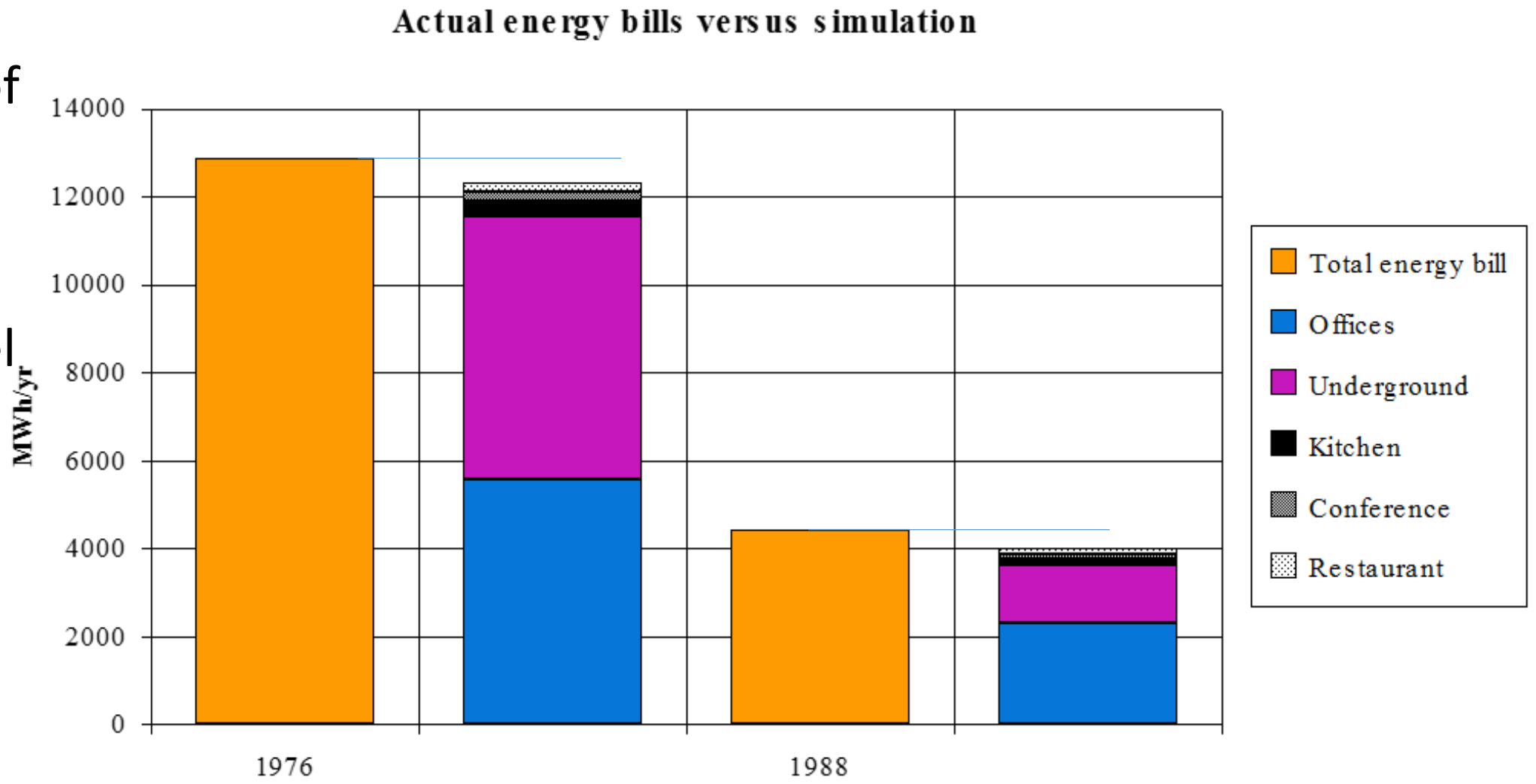




Effin'Art
The Art of Energy Efficiency

IEA 21 Werd Global retrofit analysis comparison (heating energy)

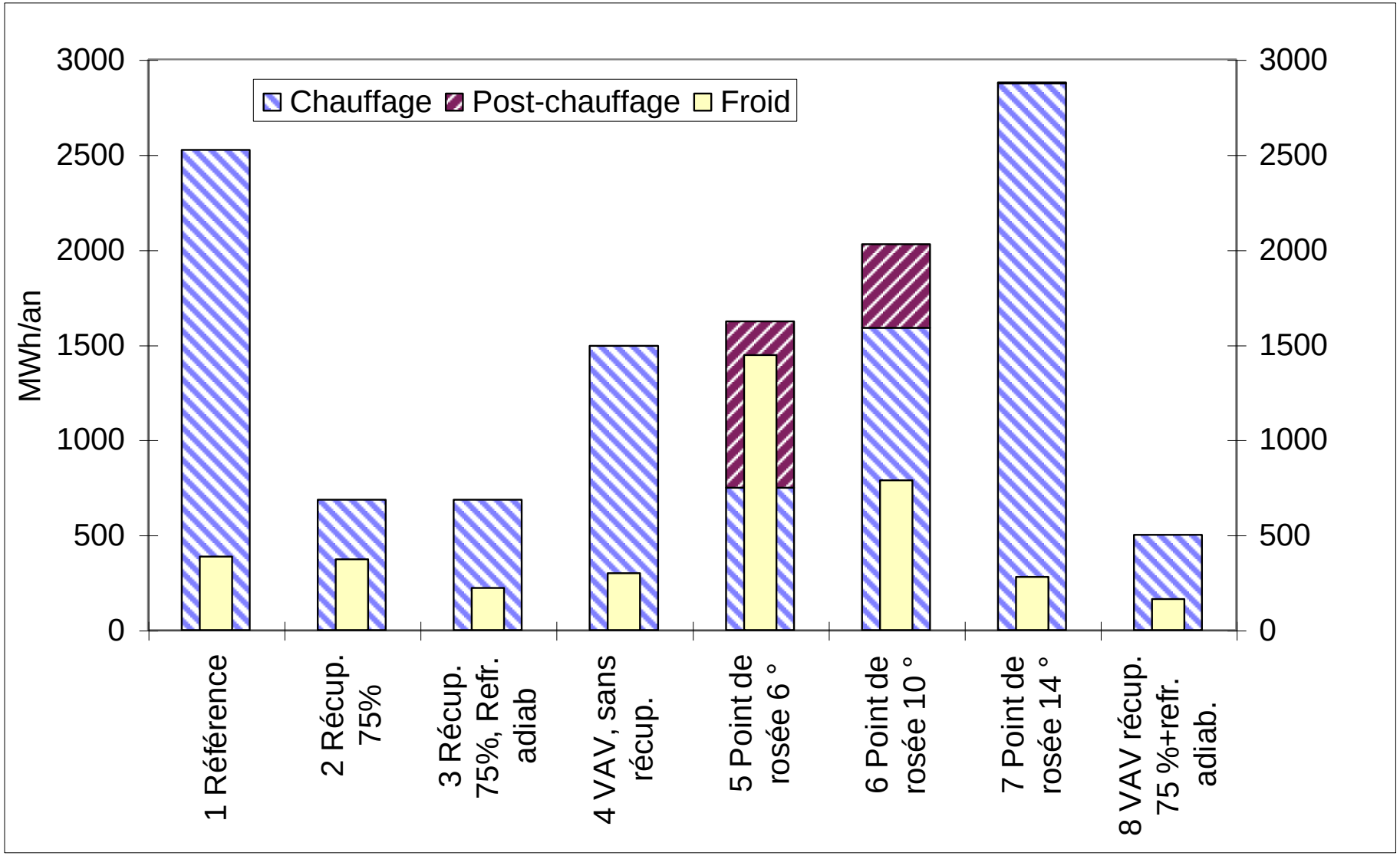
- Comparison of actual retrofit results (1976 → 1988)
- TRNSYS model with AHU developed routine
- General good agreement



Effin'Art
The Art of Energy Efficiency

IEA 21 retrofit study

- Comparison of different AHU strategies with TRNSYS
- Without and with heat recovery
- Adiabatic cooling
- Dew point control
- Reheating
- VAV



Effin'Art
The Art of Energy Efficiency

IEA 21 Retrofit study: conclusions for the practice

- It was the first time that such an hourly analysis allowed comparing quantitavely different strategies and AHU's controls with humidification
- The development of the AHU TRNSYS routine has been used quite extensively for other retrofit projects

Effin'Art
The Art of Energy Efficiency

IEA Task 12 SHC

Atrium Models for the Analysis of Thermal Comfort and Energy Use

A Report of Task 12
Building Energy Analysis and
Design Tools for Solar Applications

Project A.3 Atrium Model Development

Project contribution by D. Aiulfi when employed by Sorane

Effin'Art
The Art of Energy Efficiency

3.10 Attached atrium of the University of Neuchâtel simulated with the type 56 of TRNSYS

3.11 ELA atrium of the University of Trondheim simulated with type 56 of TRNSYS

List of Authors/Editors

BF **Bertil Fredlund,** Lund Institute of Technology, Department of Building Science, P.O.Box 118, S-22100 Lund
Phone +46-46-2220000, Fax +46-46-2224719

DA **Dario Aiulfi,** Sorane SA, rte de Châtelard 52, CH-1018 Lausanne
Phone +41-21-6471175, Fax +41-21-6468876

DC **Dominique Chuard,** Sorane SA, rte de Châtelard 52, CH-1018 Lausanne
Phone +41-21-371-175, Fax +41-21-6468876

Atrium Models for the Analysis of Thermal Comfort and Energy Use

A Report of Task 12
Building Energy Analysis and
Design Tools for Solar Applications

Project A.3 Atrium Model Development

Edited by
Ida Bryn and
Per Arne Schiefloe

T.12.A.3-1

Published by SINTEF Energy, Indoor Environmental Technology

Additional copies of this report can be ordered from :
SINTEF Energy, Indoor Environmental Technology
N-7034 Trondheim
NORWAY

Phone +47 73 59 39 00, Fax +47 73 59 31 86

March 1996

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

Effin'Art
The Art of Energy Efficiency

IEA 12

3.10 Attached atrium of the University of Neuchatel simulated with the type 56 of TRNSYS

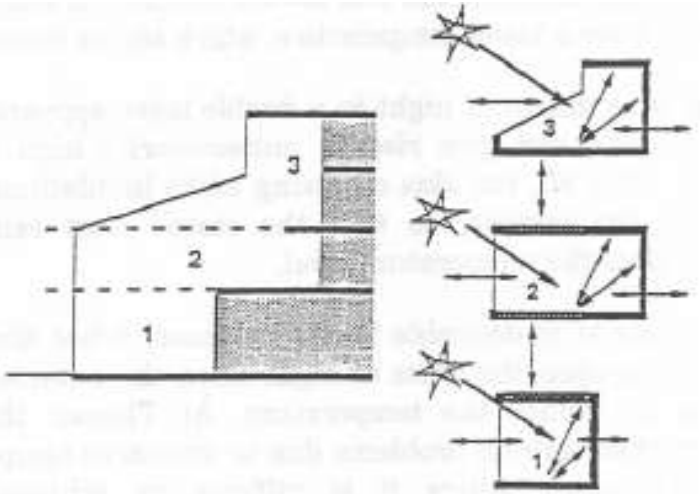


Fig. 25 Zones definition with the TRNSYS standard approach

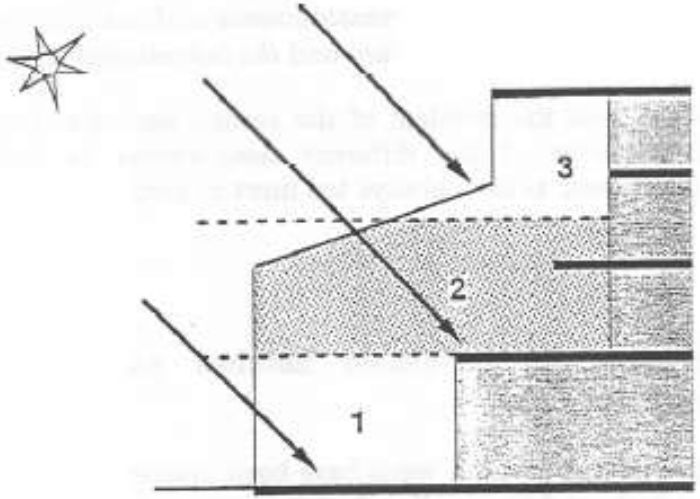


Fig. 29 New space division

Effin'Art
The Art of Energy Efficiency

b. Introduction of light surfaces

The aim of this introduction is to distribute some part of the solar gain on surfaces with low inertia. These surfaces will be heated very rapidly and will by convection give back some heat into the air rapidly.

The new comparison is presented in the next figure.

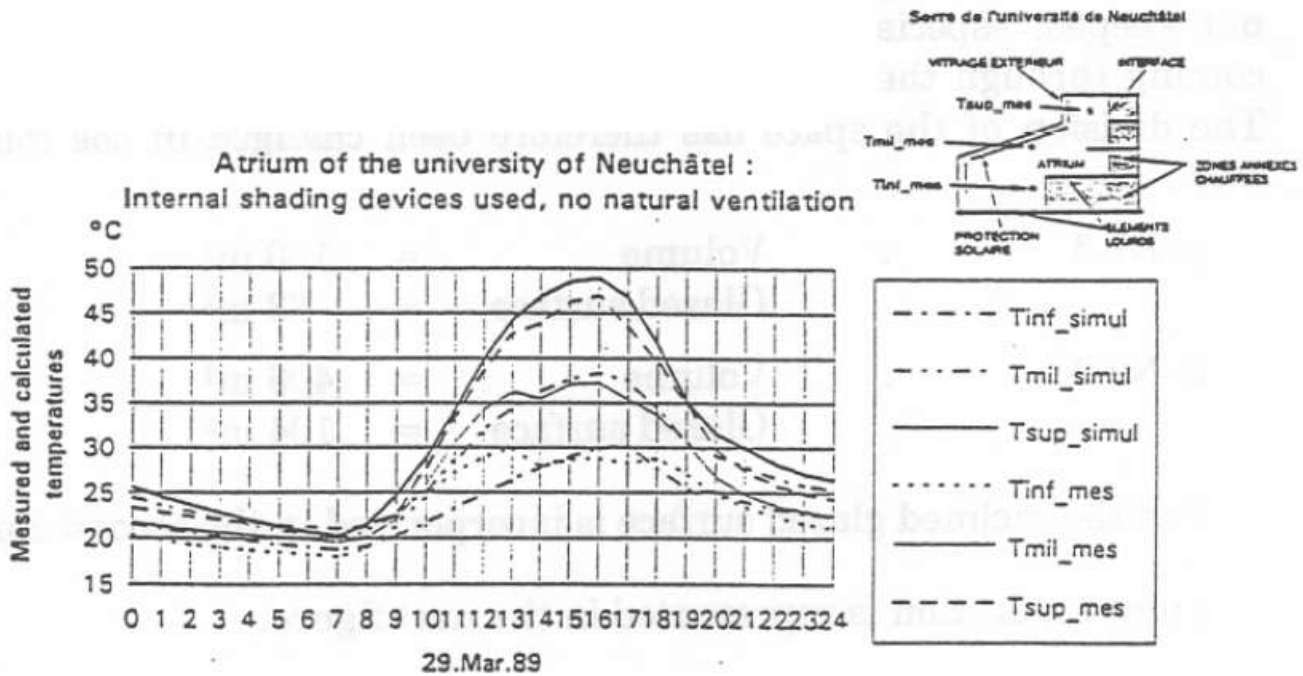


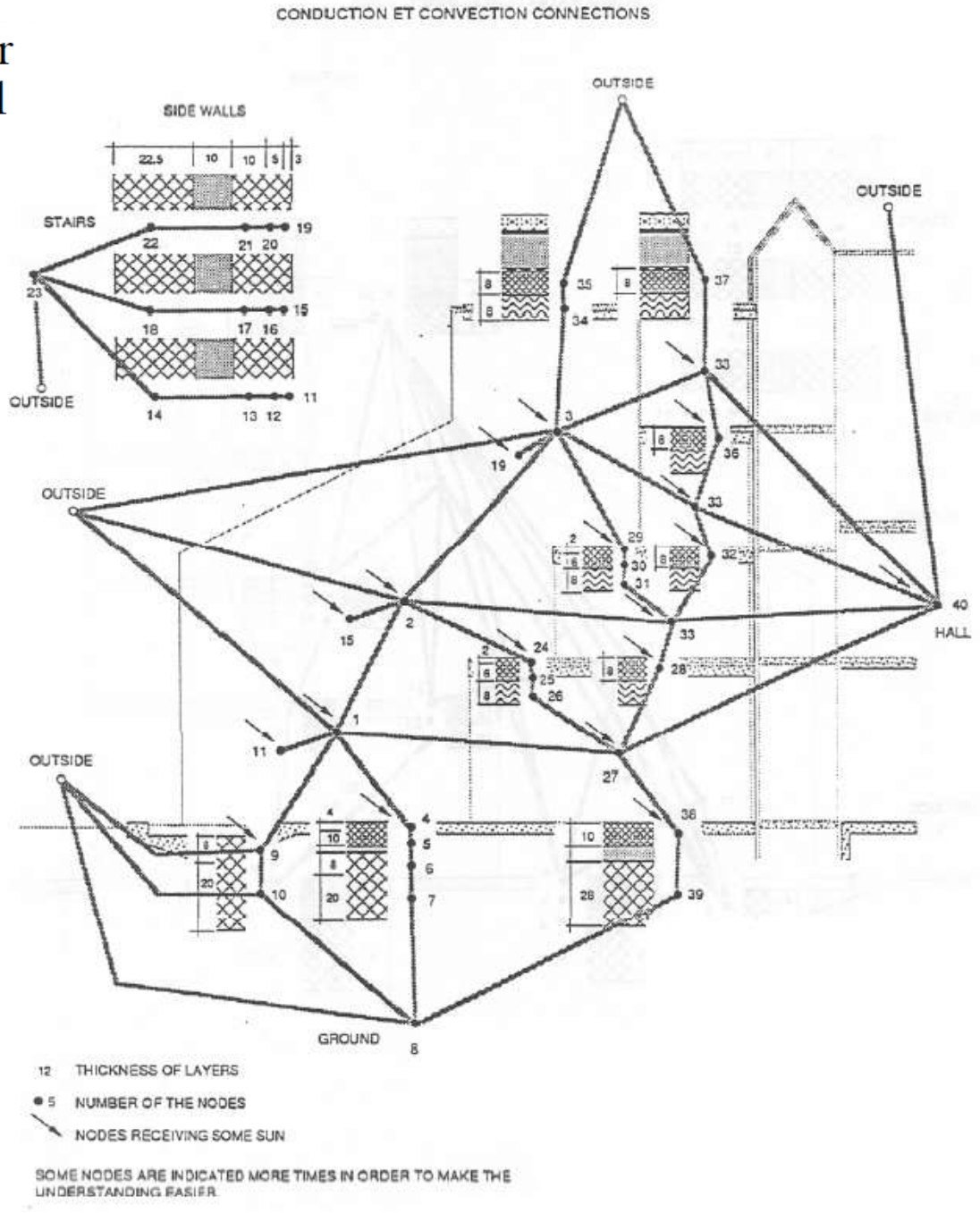
Fig. 30 Comparison between measurements and calculations with the new partitioning of the atrium and the introduction of light surfaces.

Effin'Art
The Art of Energy Efficiency

3.12 Single volume model with different air nodes and wall temperatures in the vertical direction

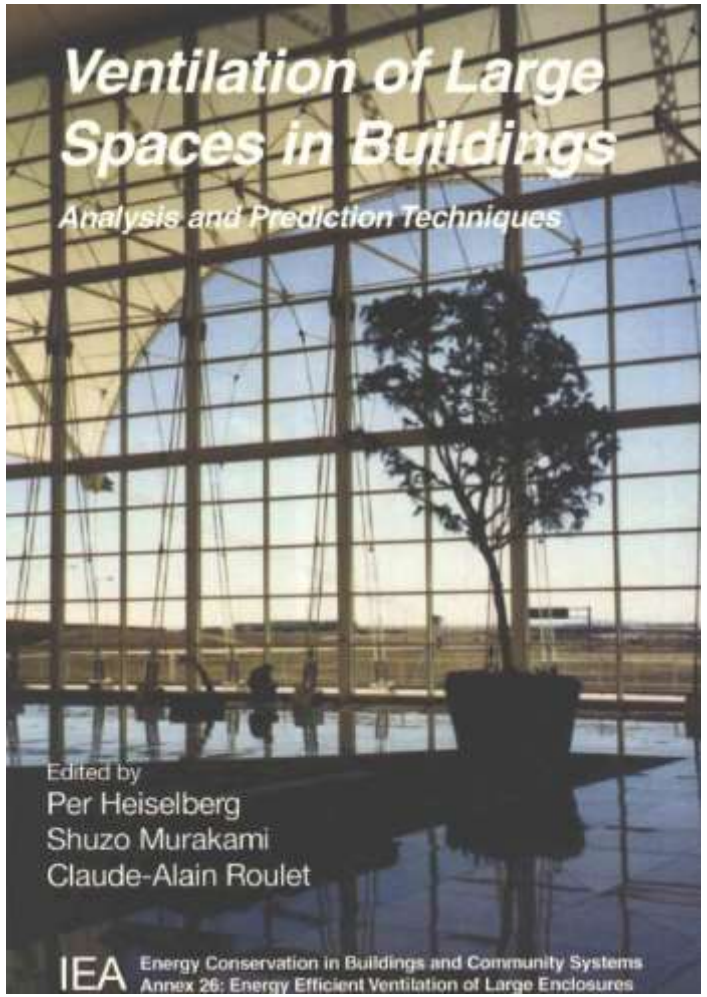
The program used to model the atrium is called MODPAS and has been developed by Sorane SA. It uses a mesh of 40 temperature nodes. These nodes can be the air of a zone as well as the surface or element temperature of a wall. Each nodes is coupled with some other nodes by symmetrical connections (conduction, convection, I.R. radiative exchanges) by non-symmetrical connection (radiative exchanges as short wave (sun) and heat gains), or by connection with the outside.

The atrium is divided in three zones, the connection mesh is presented in the next two pages.



Effin'Art
The Art of Energy Efficiency

EBC Annex 26 (1993-96) Energy Efficient Ventilation of Large Enclosures



4.6.3 Analysis Tools

Overview of model applications

- Downdraught model (P. Heiselberg)
- Natural ventilation model (D. Aiulfi)
- Thermal zonal model (J. van der Maas)
- CFD modelling to the whole of atrium 'East' (A. Schälin)

Natural ventilation (D. Aiulfi)

This simple model is based on the same principles of the natural ventilation model presented in Section 2.3.1. The model is based on the same principles as used for stack pressurisation (Equations 4.6.1 and 4.6.2). In addition, hourly solar heat gain is calculated, with and without shading devices.

The model [*Aiulfi, 1995*] is intended as a design tool to decide the necessary opening area, its type and location, such that natural ventilation by the stack-effect will be sufficient to prevent overheating in the space. Wind will normally increase the overall air exchange rate, and because the critical situation for overheating is a hot and sunny summer day without any wind, wind is not taken into account in the design. Further, the thermal inertia of the atrium has not been taken into account, so a steady-state condition is assumed. This is a conservative assumption, as overheating will usually be overestimated when thermal mass is neglected. However, many atria are lightweight spaces, so such a model will then slightly overestimate the necessary opening area, thus providing a safety margin for the designer.

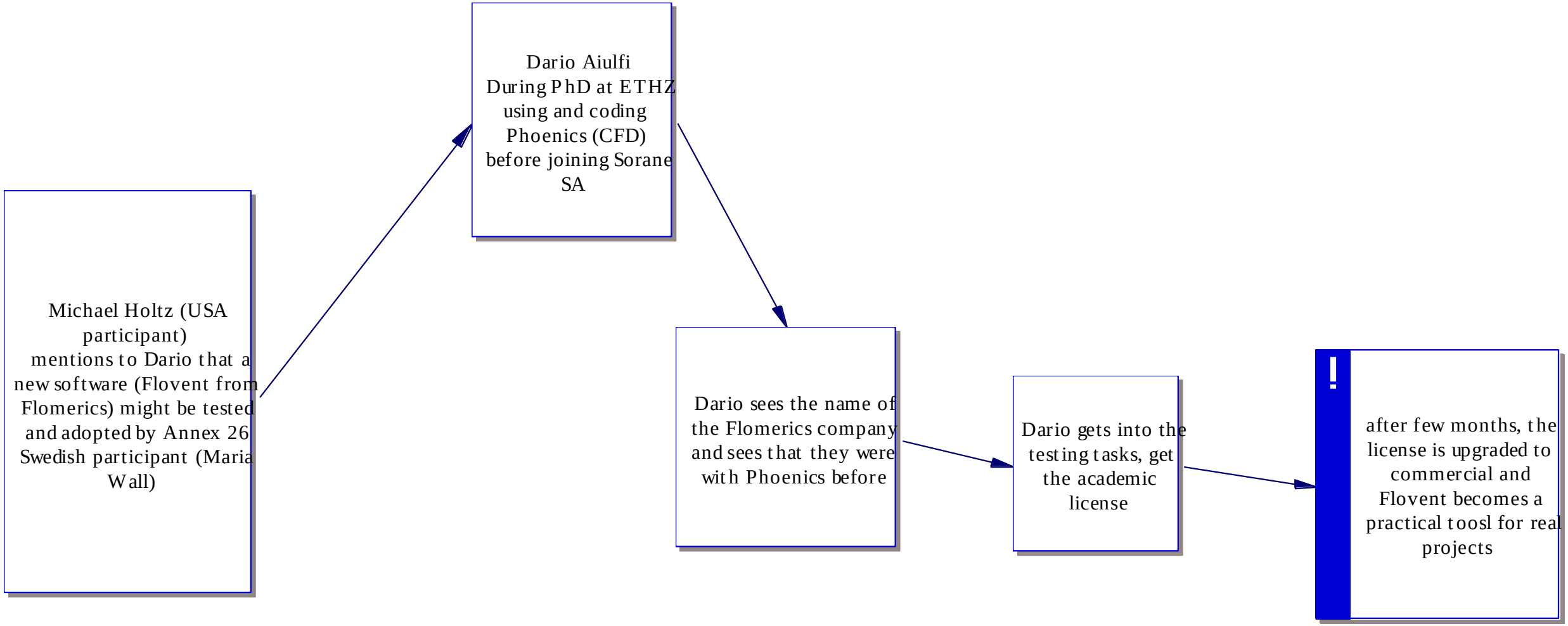
In the case of the atrium Grafenau Zug a typical hot sunny day has been simulated. Figure 4.6.13 shows the calculated exhaust air temperature for two assumptions :

- Fully mixed airflow in the space
- Linear temperature stratification. The stack flowrate is calculated assuming a linear air temperature variation between inlet and outlet

Project contribution performed by D. Aiuldif when employed by Sorane

Effin'Art
The Art of Energy Efficiency

Research network ←→ Practice
Example of successful interaction towards practical application



Effin'Art
The Art of Energy Efficiency

GEOSER (1994-2000)

- Experiment of systematic comparison
  - Reference conventional green-house
  - Green house with underground earth pipe storage
  - Green house with water storage

GEOSER
Stockage solaire à court terme en serres horticoles

Pierre Hollmuller, Bernard Lachal, Pierre Jaboyedoff, Antoine Reist, Javier Gil, Luc Danloy

STATION FEDERALE DE RECHERCHES EN PRODUCTION VEGETALE DE CHANGINS

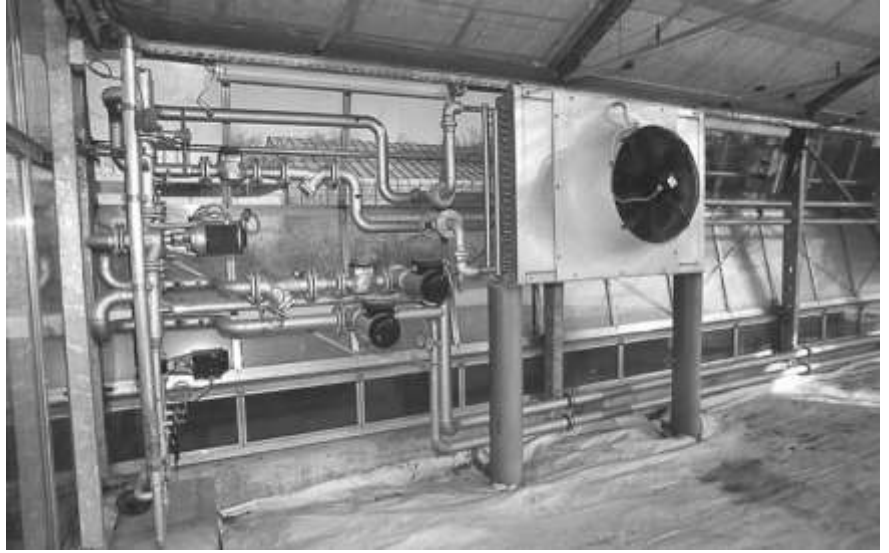
sorane sa RATIONALISATION ENERGETIQUE

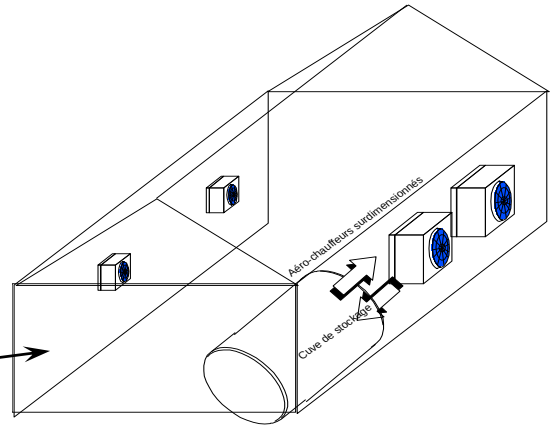
UNIVERSITÉ DE GENÈVE CENTRE UNIVERSITAIRE D'ÉTUDE DES PROBLÈMES DE L'ÉNERGIE

Project performed by PJ when employed by Sorane

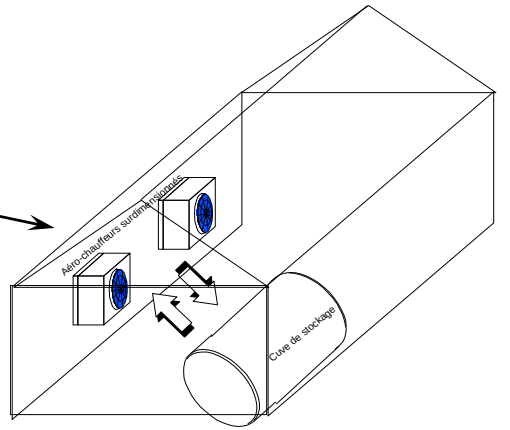
Effin'Art
The Art of Energy Efficiency

Concept of the System





- Water storage (underground)
  - Option: Storage decoupled of the heating système or integrated to the heating system
  - Selected option: Integration to heating system
  - Implication: control to be integrated with the conventional heating control (DGT)



Effin'Art
The Art of Energy Efficiency

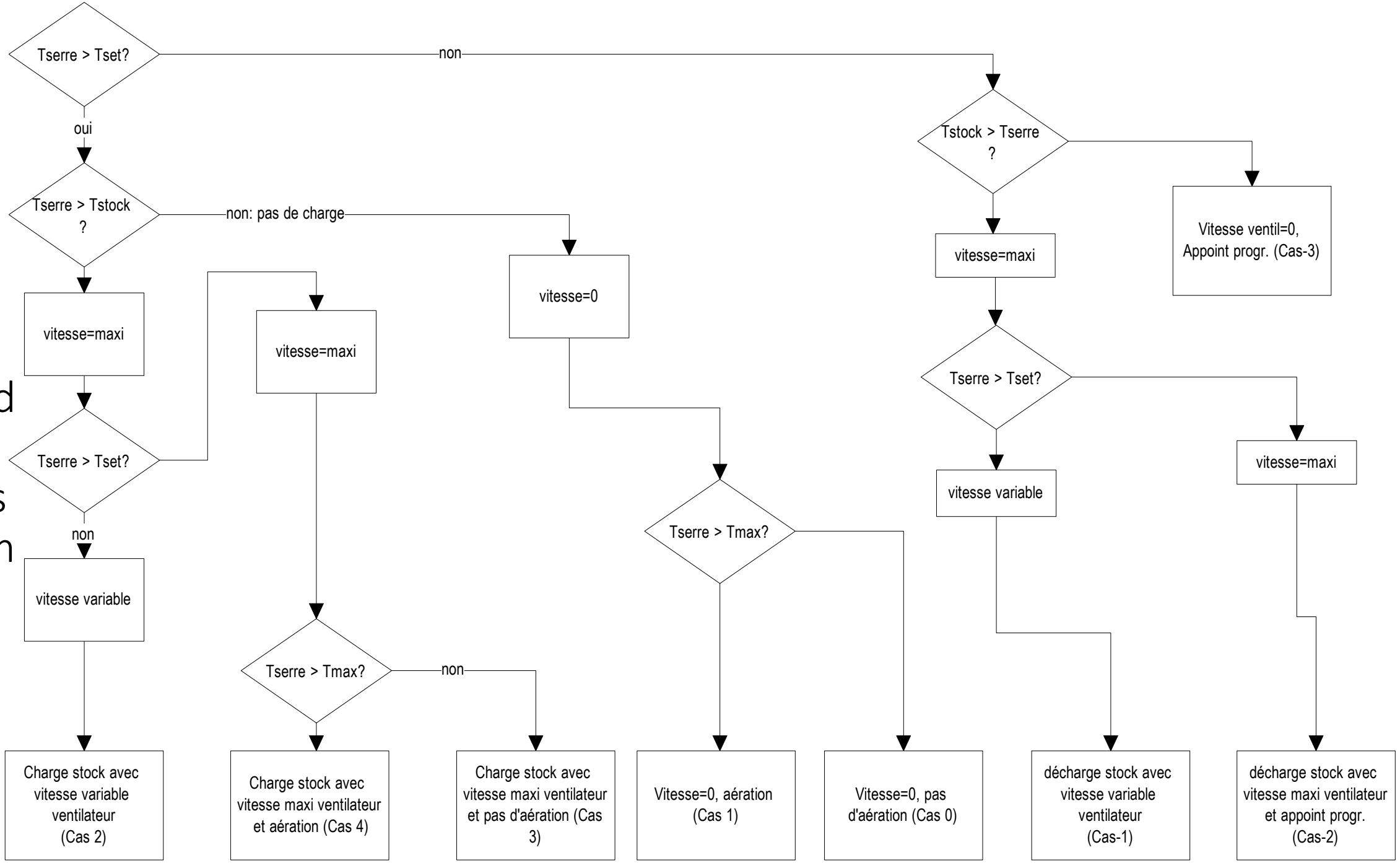
Control configuration

- Alternative options:
  - New control system: expensive and long duration
  - Separate control: poor solution
  - Integration of the control of the storage to the conventional control system, required specific development and coordination with the green house control company (DGT)
    - Selected solution

  - Experience:
  - Discussion with entreprise proposing new system not convicing as not specialized in green house control
    - e.g: shading, vents, dry and wet bulb measurement with strong radiation
  - Co-development with the Danish company DGT-Volmatic

Effin'Art
The Art of Energy Efficiency

Control cases and main decisions algorithm



Effin'Art
The Art of Energy Efficiency

Model concept and development

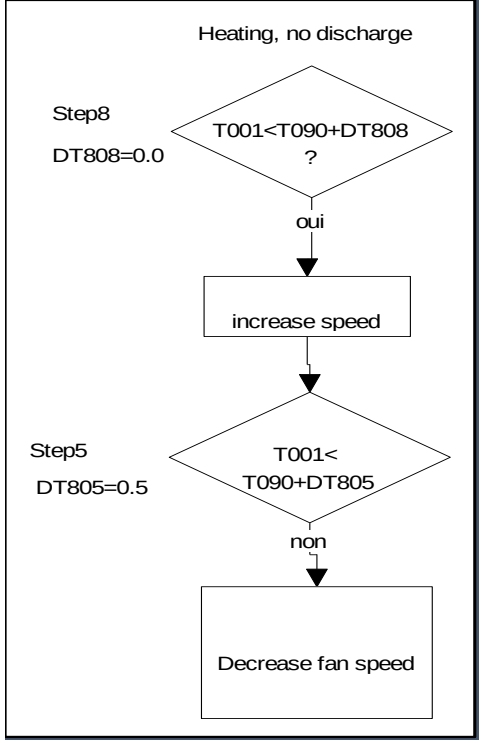
- Dynamic simulation model (TRNSYS)
  - Comparison measures-simulation
  - Control model developed for TRNSYS
  - Evapo-transpiration model for cucumber
  - Venting model specific for agricultural green-house

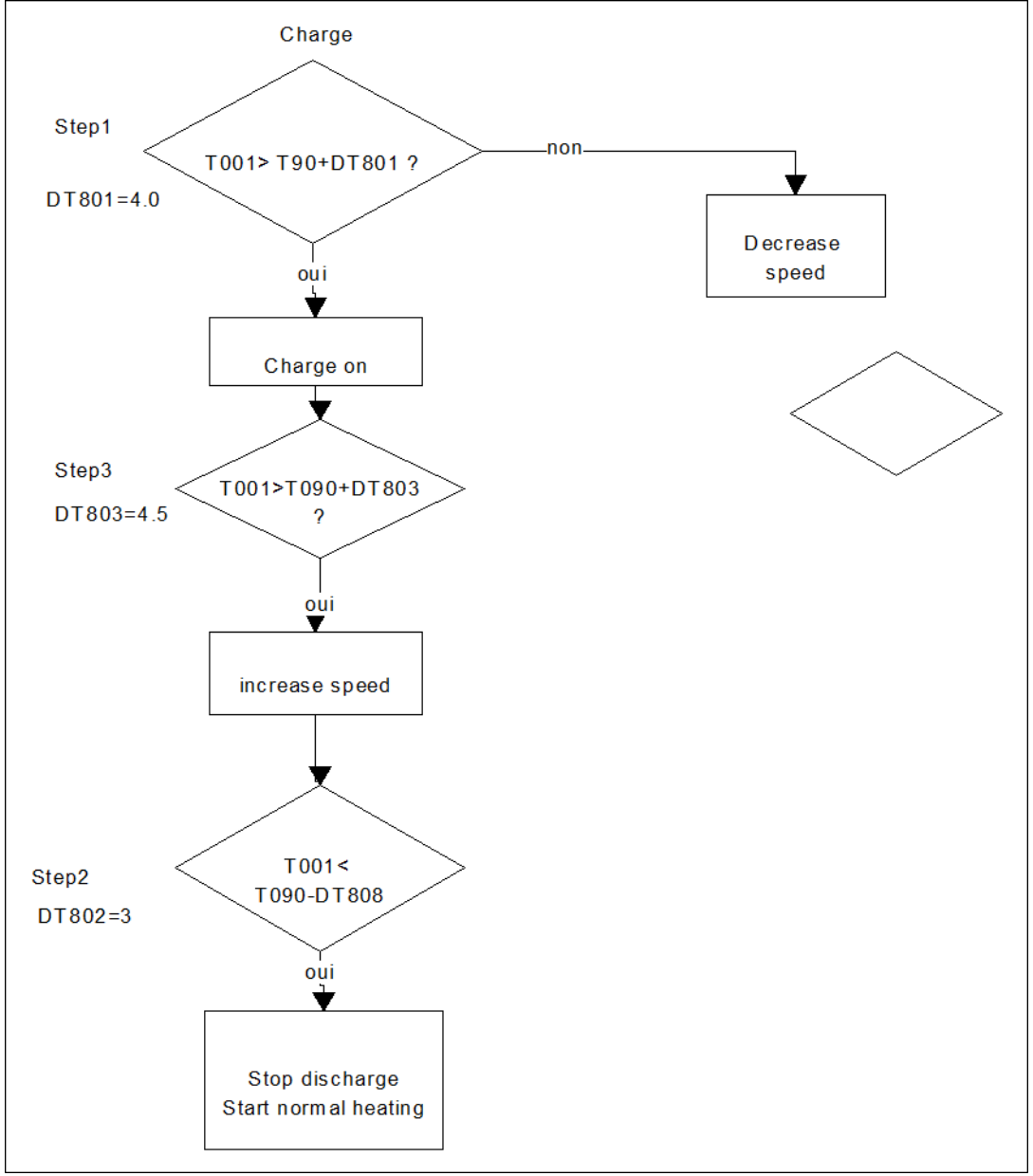
  - Using the same "trick" to control the TRNSYS convergence and reiteration and next time step

Effin'Art
The Art of Energy Efficiency

Actual development and testing on site with DGT

- Test and commissioning perfomed jointly with the DGT-Volmatic company
- Systematic of all cases

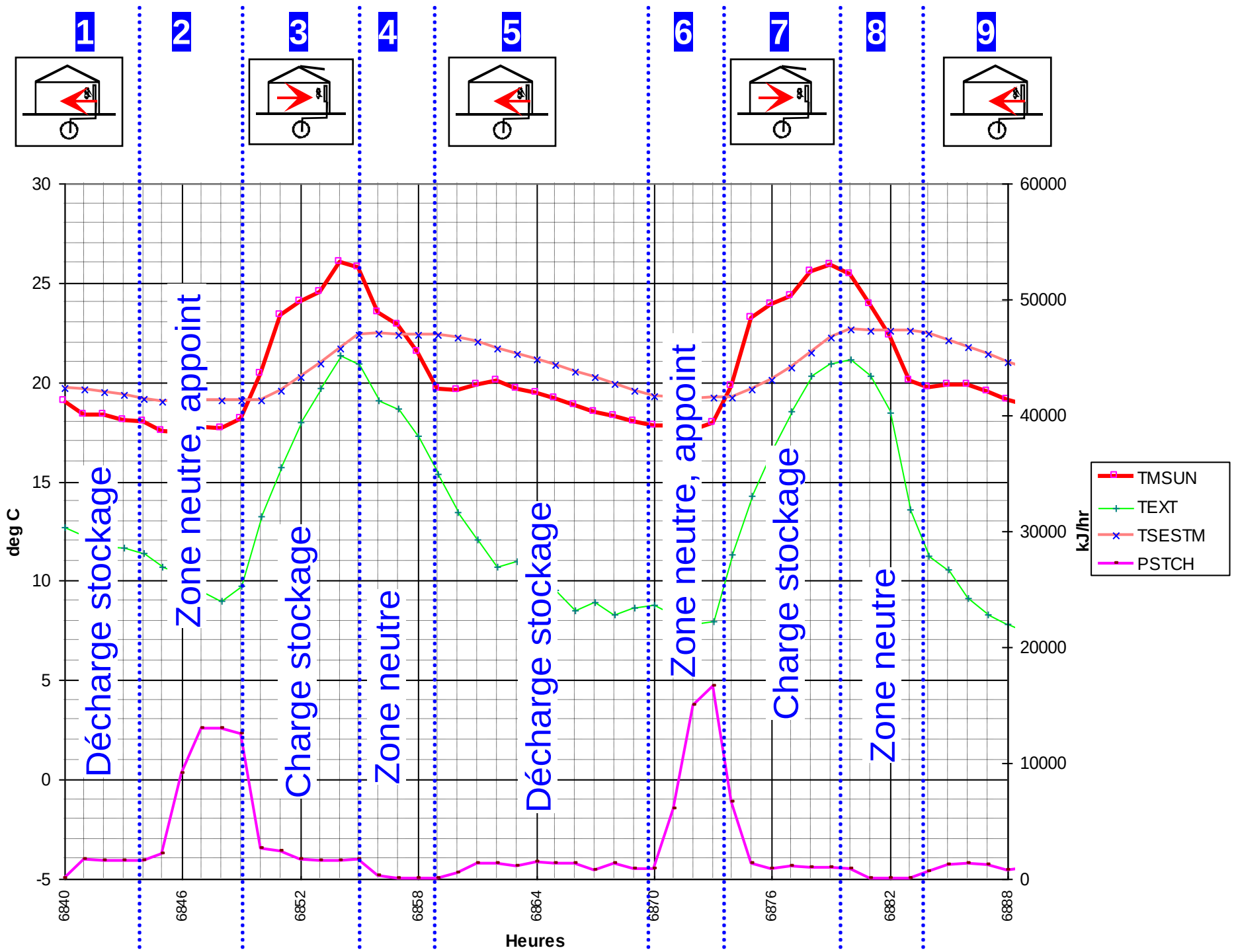




						Inputs to Micro-1			Internal Registers			Outputs from Micro-1			
Delt_charge	Dcode_801	4.00	1	Step1	Start charge	i_0000	(0)	|/|	ir_0401	1	| |	Increase fan speed	o_0200	(0)	|/|
Delt_nocharge	Dcode_802	3.00	2	Step2	Stop charge	i_0001	(1)	| |	ir_0402			Decrease fan speed	o_0201	(0)	|/|
Delt_incspeed	Dcode_803	4.50	3	Step3	Increase speed	i_0002	(0)	|/|	ir_0403		|/|	Fan active	o_0202	(1)	| |
	Dcode_804	2.00	4	Step4	Tank fully charged	i_0003	(1)	| |	ir_0404		|/|	Open valve 1	o_0203	(0)	|/|
	Dcode_805	2.00	5	Step5	Start discharge	i_0004	(1)	| |	ir_0405		|/|	Close valve 1	o_0204	(1)	| |
	Dcode_806	2.50	6	Step6	Stop discharge	i_0005	(0)	|/|				Pump active	o_0205	(1)	| |
	Dcode_807	-2.00	7	Step7	Tank empty	i_0006	(0)	|/|	ir_0420	0	|/|	Open valve 2	o_0210	(0)	|/|
	Dcode_808	0.00	8	Step8	Increase fan speed	i_0007	(0)	|/|	ir_0421		|/|	Close valve 2	o_0211	(1)	| |
	Dcode_809	-0.50	9	Step9	Increase speed by heat	i_0010	(0)	|/|	ir_0422		|/|	Open valve 3	o_0212	(1)	| |
			10	Step10	Primary valve open	i_0011	(0)	|/|				Close valve 3	o_0213	(0)	|/|
			11	Step11	Primary valve close	i_0012	(0)	|/|	ir_0430	1	| |	Open valve 4	o_0214	(0)	|/|
Tairgreenhouse	Mcode_1	20.20	12	Step12	Pump primary	i_0013	(0)	|/|	ir_0431		|/|	Close valve 4	o_0215	(1)	| |
Setpoint greenhouse	Rcode_90	20.50	13	Step13	Manual selector 1.1	i_0014	(1)	| |	ir_0432		|/|				
Ttop	Rcode_880	24.30	14	Step14	Manual selector 1.2	i_0015	(1)	| |	ir_0433		|/|				
Tbottom	Rcode_881	22.20	15	Step15	Manual selector 2.1	i_0016	(1)	| |							
			16	Step16	Manual selector 2.2	i_0017	(1)	| |							

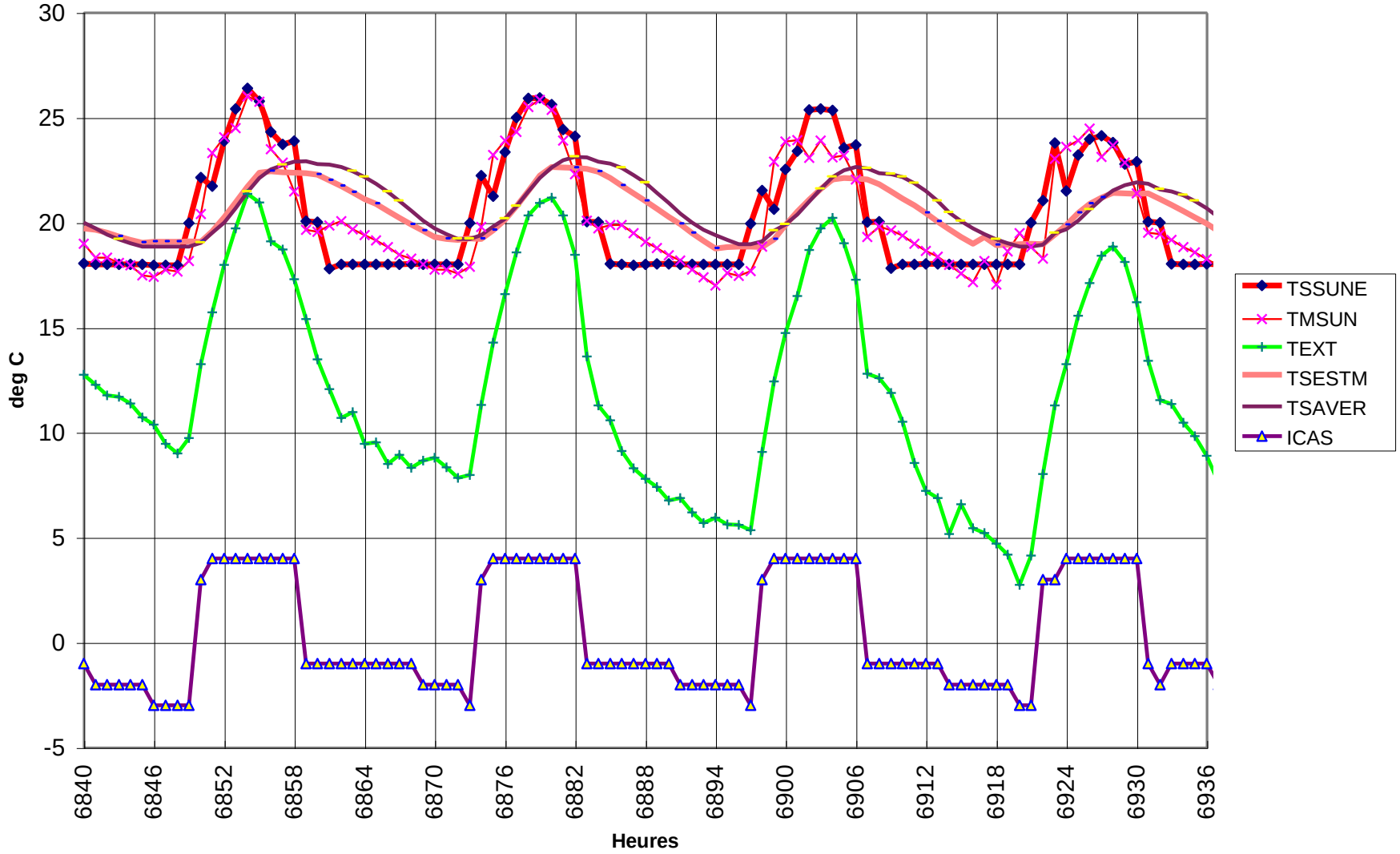
Effin'Art
The Art of Energy Efficiency

Typical control sequence 2 days



Effin'Art
The Art of Energy Efficiency

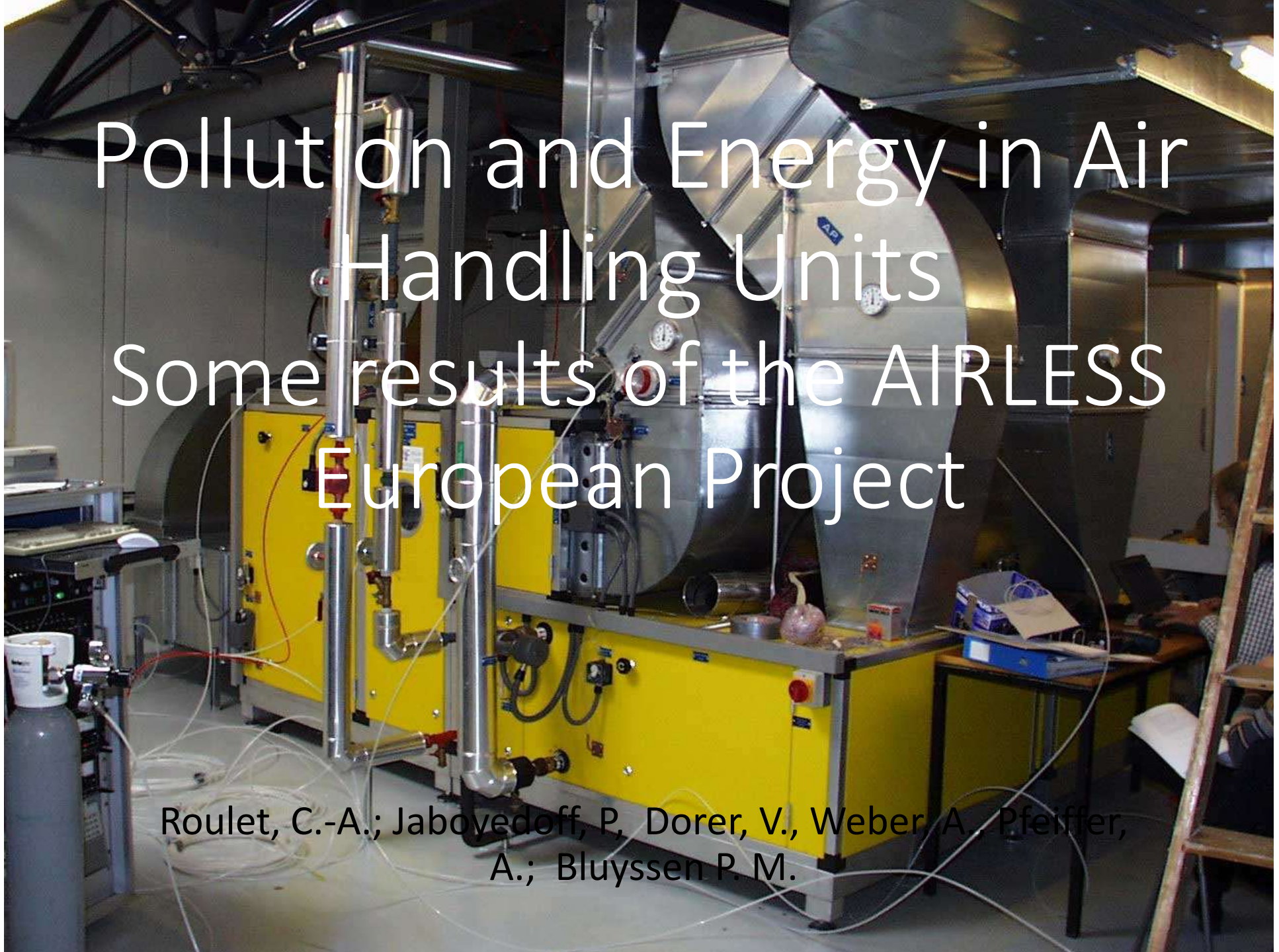
Measurment and simulation for the water storage green house



Effin'Art
The Art of Energy Efficiency

GEOSER conclusions

- Using the previous experience of control module developed during the SOFAS project, the development was quite rapid
- The measured results and simulated did match quite well
- The saving potential with the water storage is of the order of 30% saving
- The economy with the oil price at this time was not favourable for the reproduction in large scale
- The knowledge developed during this project stays for future application when energy price would be higher
- The design developed could be easily used in the practice when financial conditions would be favorable



Pollution and Energy in Air Handling Units
Some results of the AIRLESS European Project

Roulet, C.-A.; Jabovedoff, P, Dorer, V., Weber, A., Pfeiffer, A.; Bluyssen P. M.

Effin'Art
The Art of Energy Efficiency

AIRLESS
1998-2001

- **Design, Operation and Maintenance Criteria for Air Handling Systems and Components for better Indoor Air Quality and Lower Energy Consumption**
- **Main objective: To develop strategies, principles and protocols to improve and control the performance of HVAC-systems and its components for incorporation in codes and guidelines**

Effin'Art
The Art of Energy Efficiency

12 PARTICIPANTS from 7 countries

TNO Building and Construction Research (NL)
Helsinki University of Technology (FIN)
Technische Universität Berlin (D)
IDMEC, Universitad do Porto (P)
Swiss Federal Institute of Technology Lausanne (CH)
Technical University of Denmark (DK)
Halton Oy (FIN)
Heinrich Nickel GmbH (D)
Universitad de Sevilla (E)
Sulzer-Infra Labs Ltd (CH)
Swiss Federal Materials Testing Lab
Sorane SA (CH)

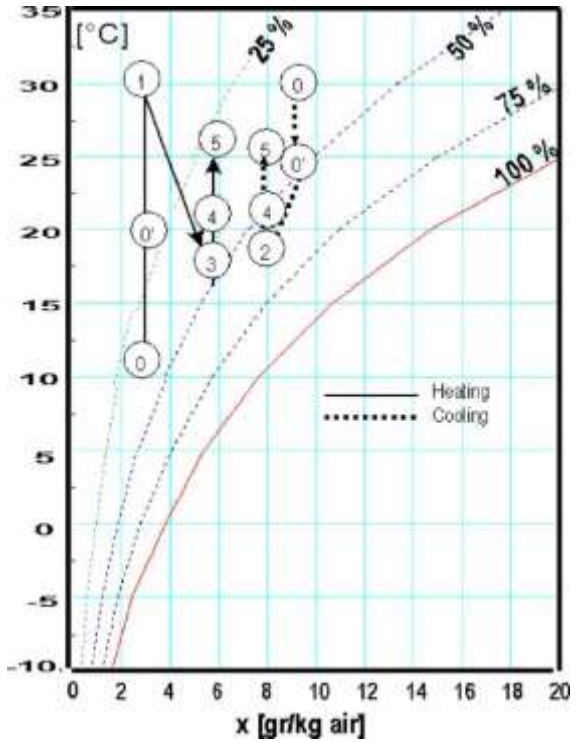
Effin'Art
The Art of Energy Efficiency

AIRLESS

P. Jaboyedoff et al. / Energy and Buildings 36 (2004) 391–399

- Energy in air-handling units—results of the AIRLESS European Project

- P. Jaboyedoff [a,*], C.-A. Roulet [b], V. Dorer [c], A. Weber [c], A. Pfeiffer



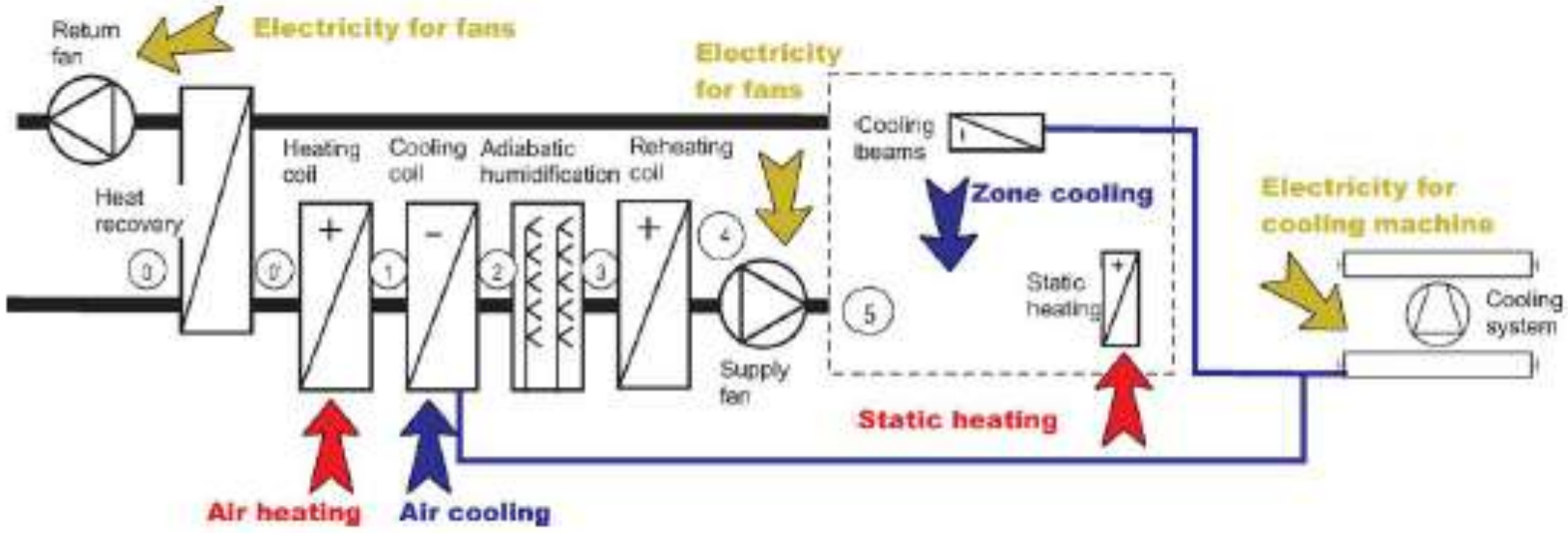


Fig. 3. Schematics of the HVAC unit developed for TRNSYS and coupled with TRNSYS building model.

AIRLESS

Effin'Art
The Art of Energy Efficiency

- Parametic variation
  - Building tightness is of highest impact on heat demand

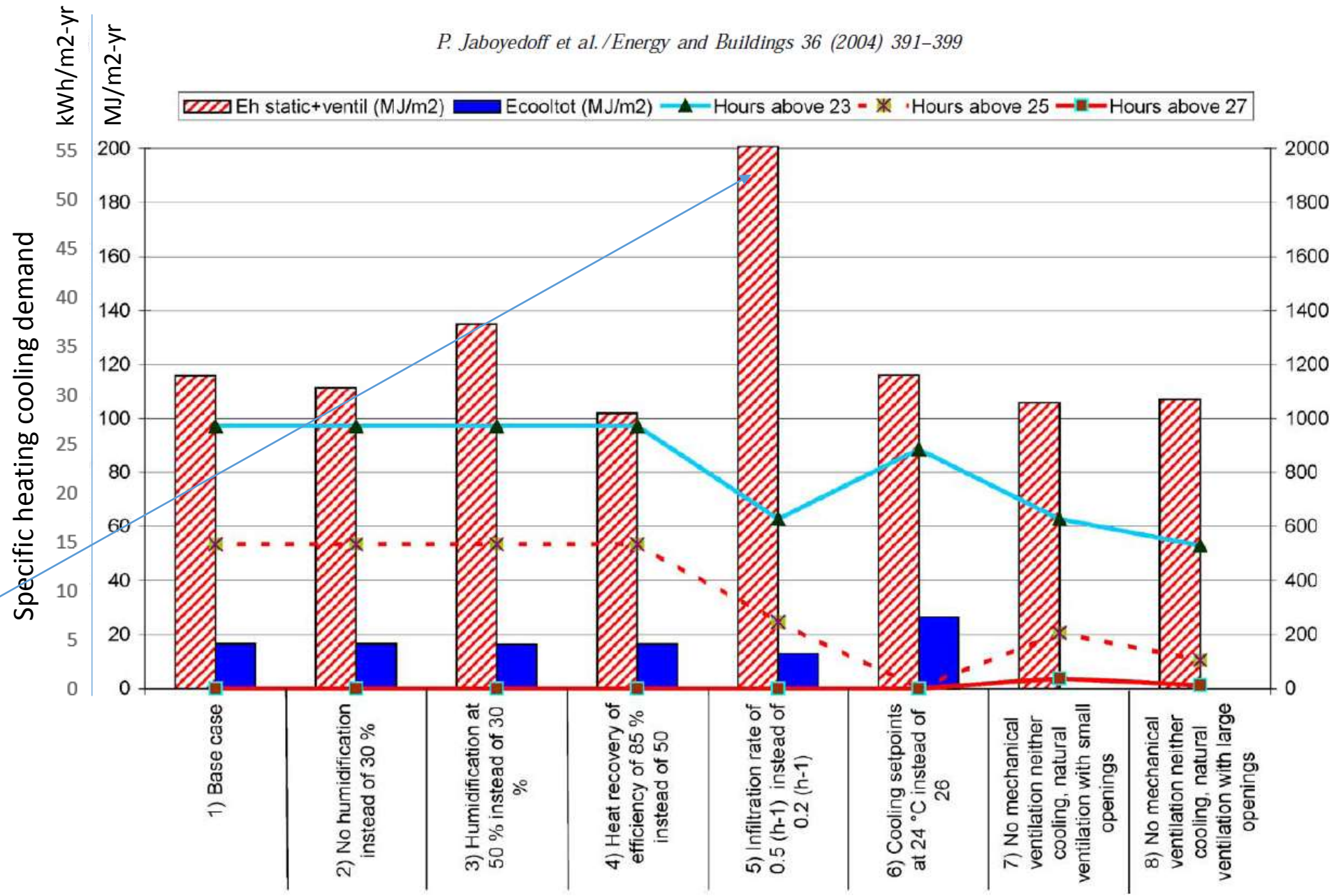


Fig. 8. Energy use and comfort conditions for several ventilation strategies: Base case: mechanical ventilation during occupation of 25 $m^3/(h\,person)$, humidification to 30%, heat recovery efficiency of 50%, infiltration rate of 0.2 (h^{-1}), cooling to 26 °C, other are variations of the base case.

Effin'Art
The Art of Energy Efficiency

IEA-SHC Task 23

The Optimisation of Solar Energy Use in large non residential buildings

- Subtask Design Process Guidelines
- Subtask leader Switzerland

Switzerland

Pierre Jaboyedoff*
SORANESA
Route de Châtelard 52
CH-1018 Lausanne
e-mail: pierre.jaboyedoff@sorane.ch
Telephone: +41 21 647 1175
Telefax: +41 21 646 8676

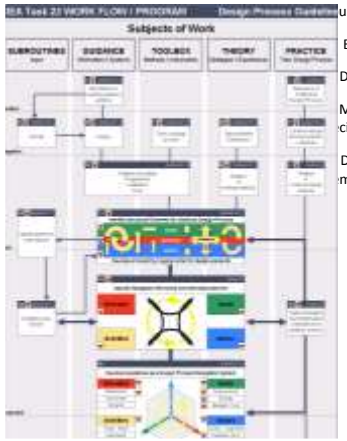
Werner Sutter
Architekten B+S
Kirchenstrasse 13
CH-6300 Zug
e-mail: sutter.werner@bluewin.ch
Telephone: +41 41 711 6144
Telefax: +41 41 711 0180

Tâche 23 du programme Solar Heating and Cooling de l'Agence Internationale de l'Energie, intitulée „The Optimisation of solar energy use in large non residential buildings"

Résultats des travaux applicables aux processus de design des grands bâtiments solaires non résidentiels (Projet financé par l'OFEN)

Auteurs : Pierre Jaboyedoff SORANE SA, Lausanne
Werner Sutter B+S Architekten, Zug

La Tâche 23 du programme Solar Heating and Cooling de l'Agence Internationale de l'Energie, a pour objectif principal de développer des recommandations pour le processus de design de grands bâtiments solaires non résidentiels. Il s'agit de développer des méthodes permettant d'assurer que les problèmes rencontrés au cours du processus soient identifiés et résolus de manière optimales.



us-Tâches:

Etudes de cas

Design process guidelines

Méthodes et outils de cisions

Dissémination et monstration

L'environnement est basé sur les principales dimensions du processus de design:

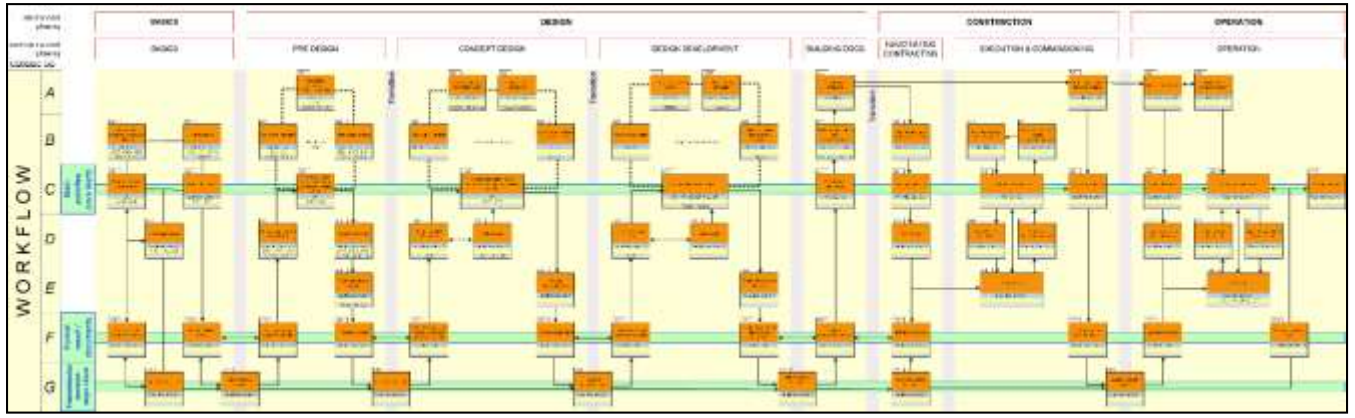
.Une description graphique du processus par sujet/activité

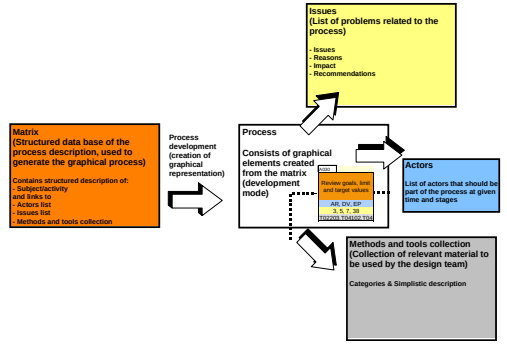
.Une liste de problèmes (Issues) qui sont liés aux différents sujet/activités

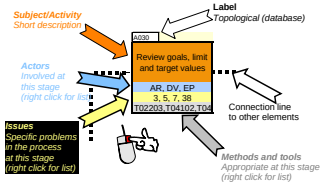
.Une liste d'acteurs qui sont/devraient être associés à des moments donnés du processus

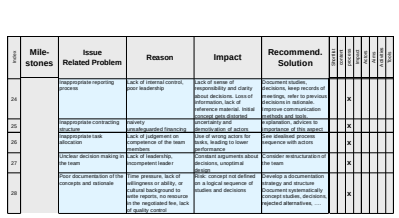
.Un liste de méthode et outils relatives à l'exécution d'un processus de design optimal du point de vue énergétique et environmental

La figure ci-dessous présente la structure de principe de l'environnement.









Mile-stones	Issue Related Problem	Reason	Impact	Recommend. Solution
	Inappropriate reporting process	Lack of internal control, poor leadership	Lack of sense of responsibility and clarity about decisions. Loss of information, lack of reference material. Initial planned aims distorted	Document studies, decisions, keep records of meetings, refer to previous documentation, ... Improve communication methods and tools
	Inappropriate contracting structure	waivery predisposition financing	uncertainty and demotivation of actors	x
	Inappropriate task allocation	Lack of judgement on competence of the team members	Use of wrong actors for tasks, leading to lower performance	x
	Unclear decision making in the team	Lack of leadership, incompetent leader	Constant arguments about decisions, unoptimal design	x
	Poor documentation of the concepts and rationale	Time pressure, lack of willingness or ability, or cultural background to write reports, no resource in the negotiated fee, lack of quality control	Risk: concept not defined on a logical sequence of studies and decisions	Develop a documentation strategy and structure. Document systematically concept studies, decisions, rejected alternatives, ... x

Effin'Art
The Art of Energy Efficiency

„Linking TRNSYS with EES – solar desiccant cooling“ EES model for concept evaluation

- Presented at the TRNSYS used day at Stuttgart 2003

A0 = 0.81

Adiff = 0.63

K0 = 2.4

$peti_b$ = 0.006

diff = 0.26

$Area_{cap}$ = 400

$facteur_{dessic}$ = 1.2

lecture fichier

$Heure_i$ = **Lookup** ('7–15', i, 'Heures') for i = 1 to 24

$Text_i$ = **Lookup** ('7–15', i, 'Text') for i = 1 to 24

$rH_i = \frac{\textbf{Lookup}\ (\text{'7–15'},\ i,\ \text{'rH'})}{100}$ for i = 1 to 24

$Global_i$ = **Lookup** ('7–15', i, 'Global') for i = 1 to 24

$P_{gains,int,i}$ = **Lookup** ('Gains', i, 'Gains_{int}') for i = 1 to 24

$P_{gains,sol,i}$ = **Lookup** ('Gains', i, 'Gains_{sol}') for i = 1 to 24

$P_{gains,tot,i} = P_{gains,int,i} + P_{gains,sol,i}$ for i = 1 to 24

$T5_i$ = 25 for i = 1 to 24

Taux de recirculation

$Recirc_i$ = 0.001 for i = 1 to 24

Efficacité de la récupération en enthalpie

$effict_i$ = 0.8 for i = 1 to 24

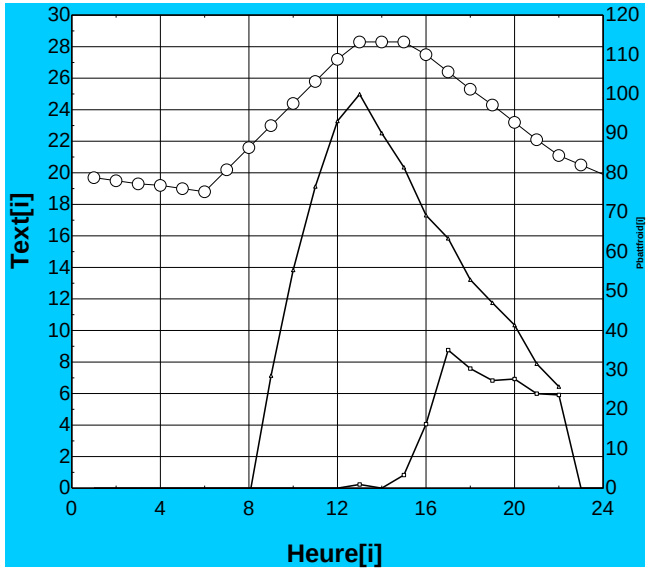
$switch_{lave,i}$ = 1 for i = 1 to 24

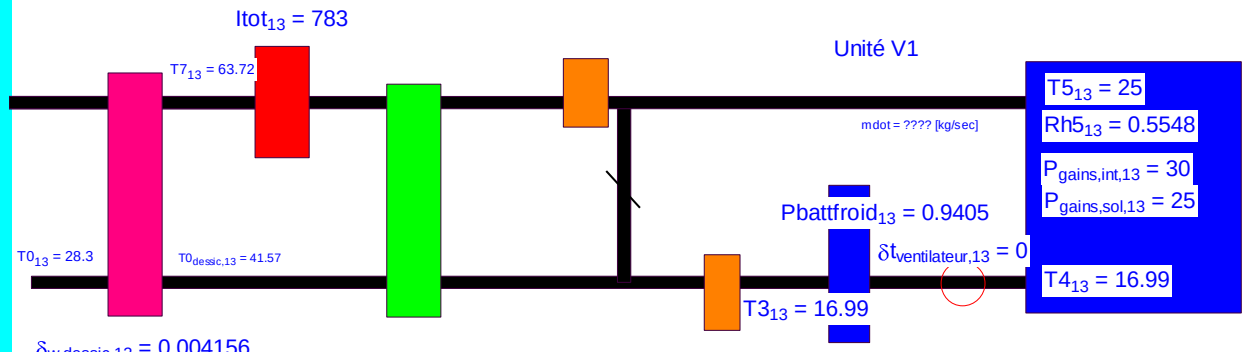
$Rh2_{lave,set,i}$ = 0.9 for i = 1 to 24

lavage air sortant

$switch_{sature,i}$ = 1 for i = 1 to 24

- Manufacturer data based correlation for dessiccant wheel
- Set of equations to model the HVAC unit
- 24 hours simplifed model





Work performed by PJ when employed by Sorane

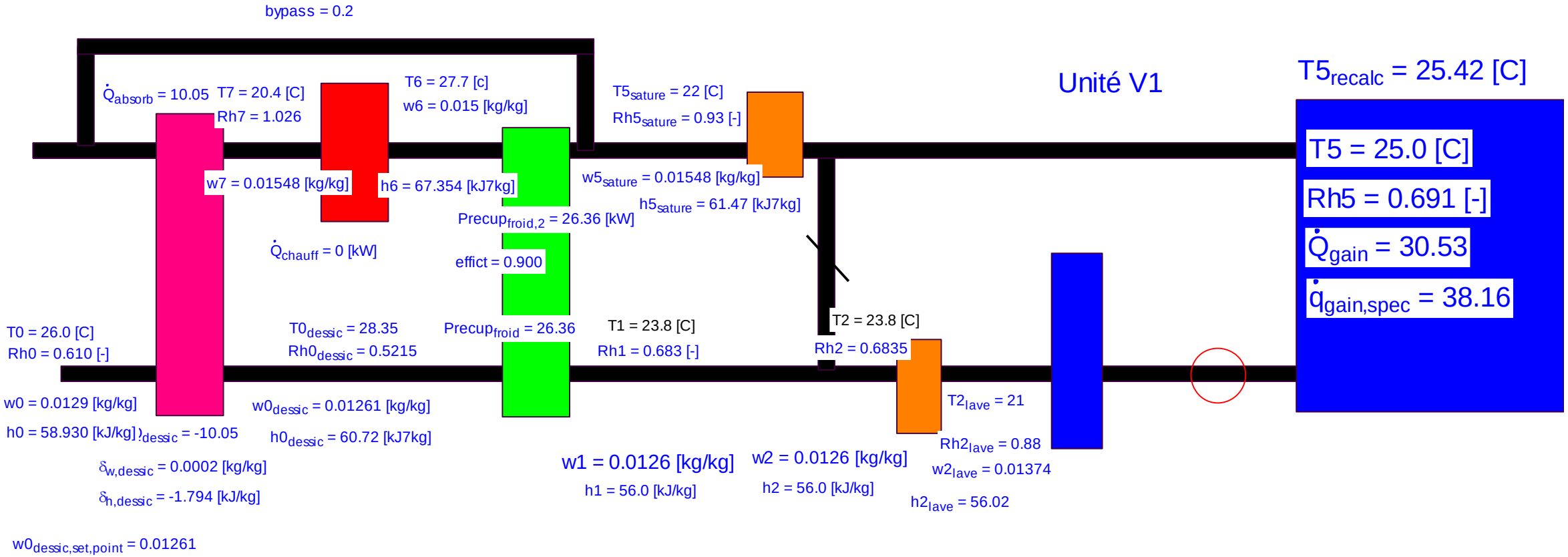
Effin'Art
The Art of Energy Efficiency

First feasibility

- Standalone EES model
- TRNSYS solar installation
- No dynamic coupling
- « Hand transfer » of data from EES to TRNSYS model

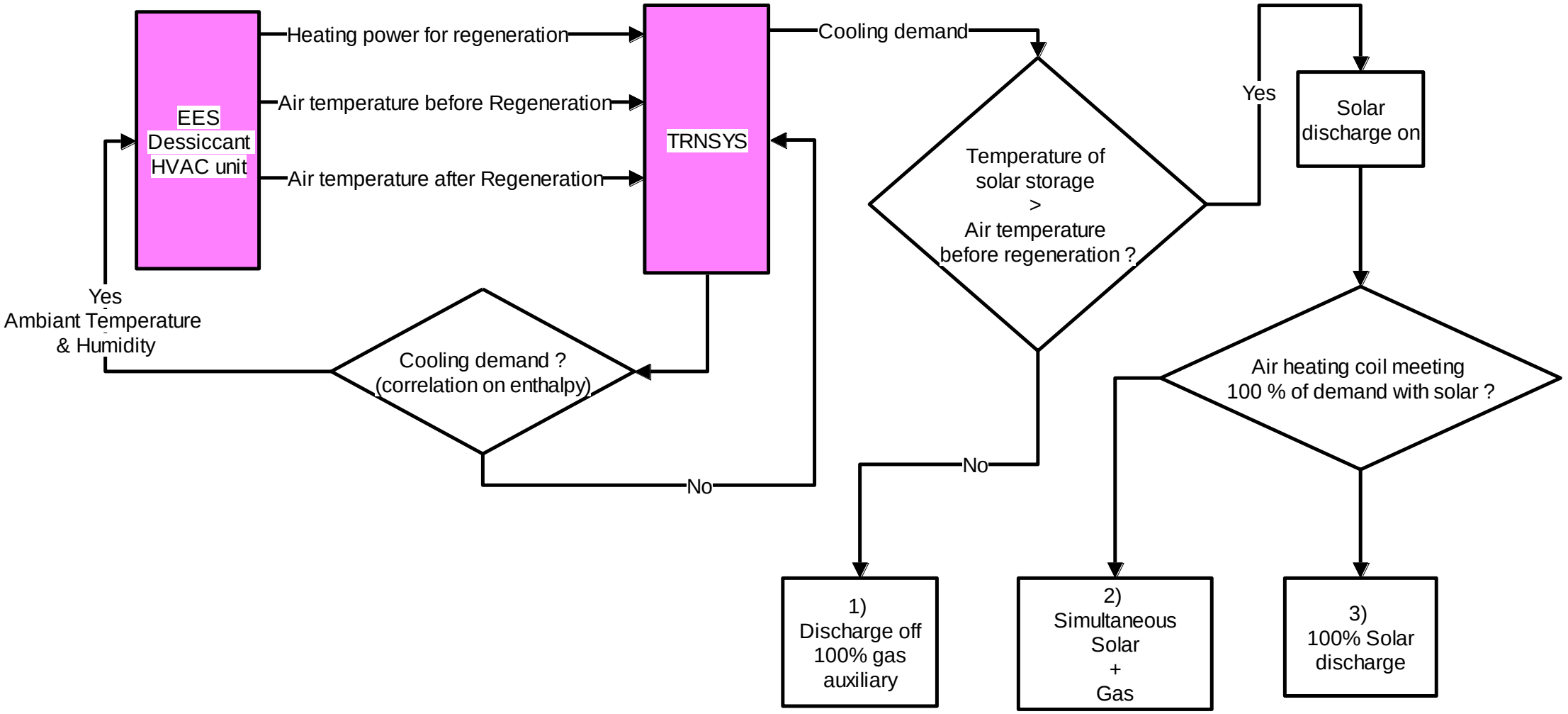
Effin'Art
The Art of Energy Efficiency

EES Model for TRNSYS coupling



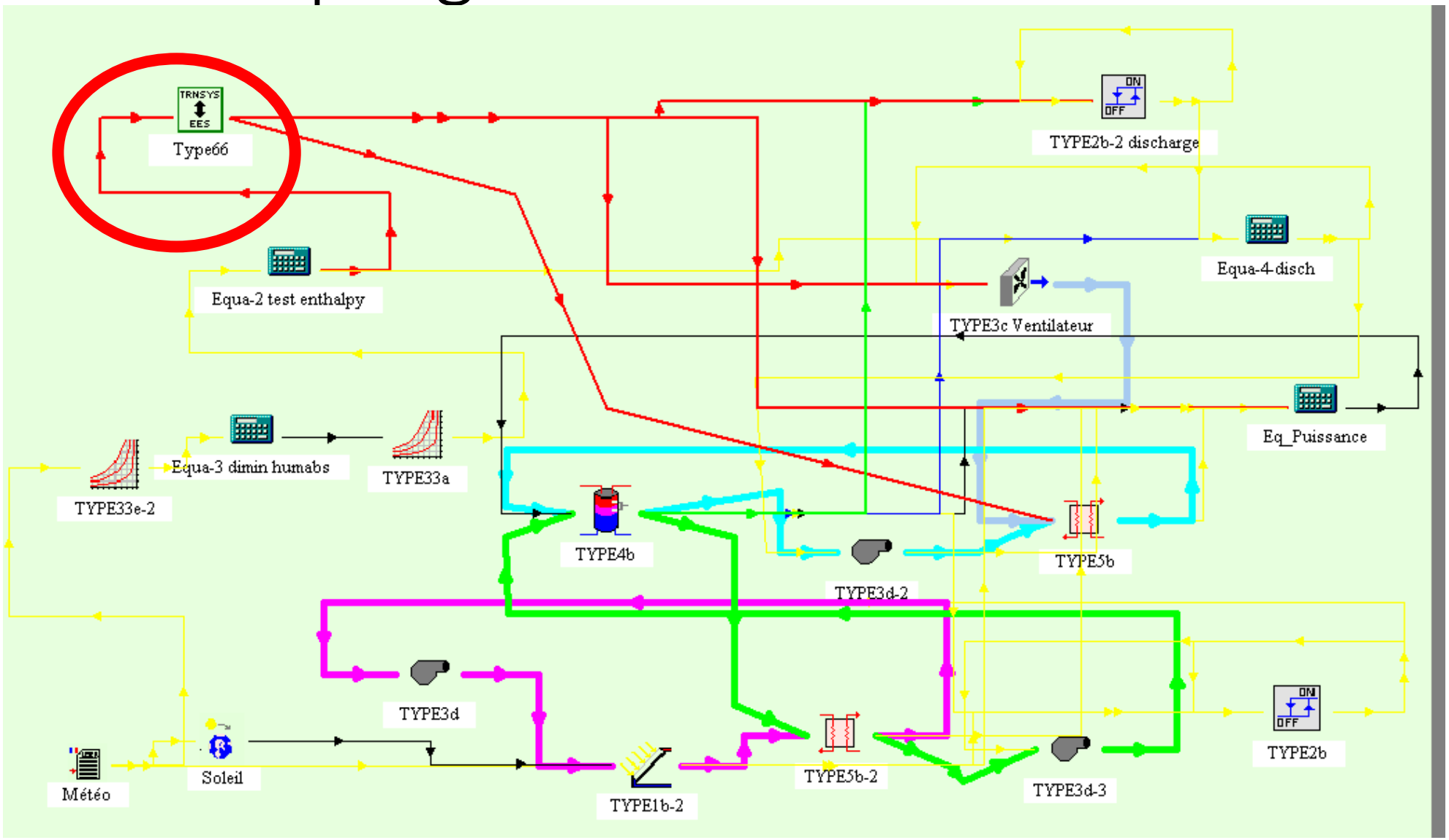
Effin'Art
The Art of Energy Efficiency

TRNSYS EES
Coupling principle



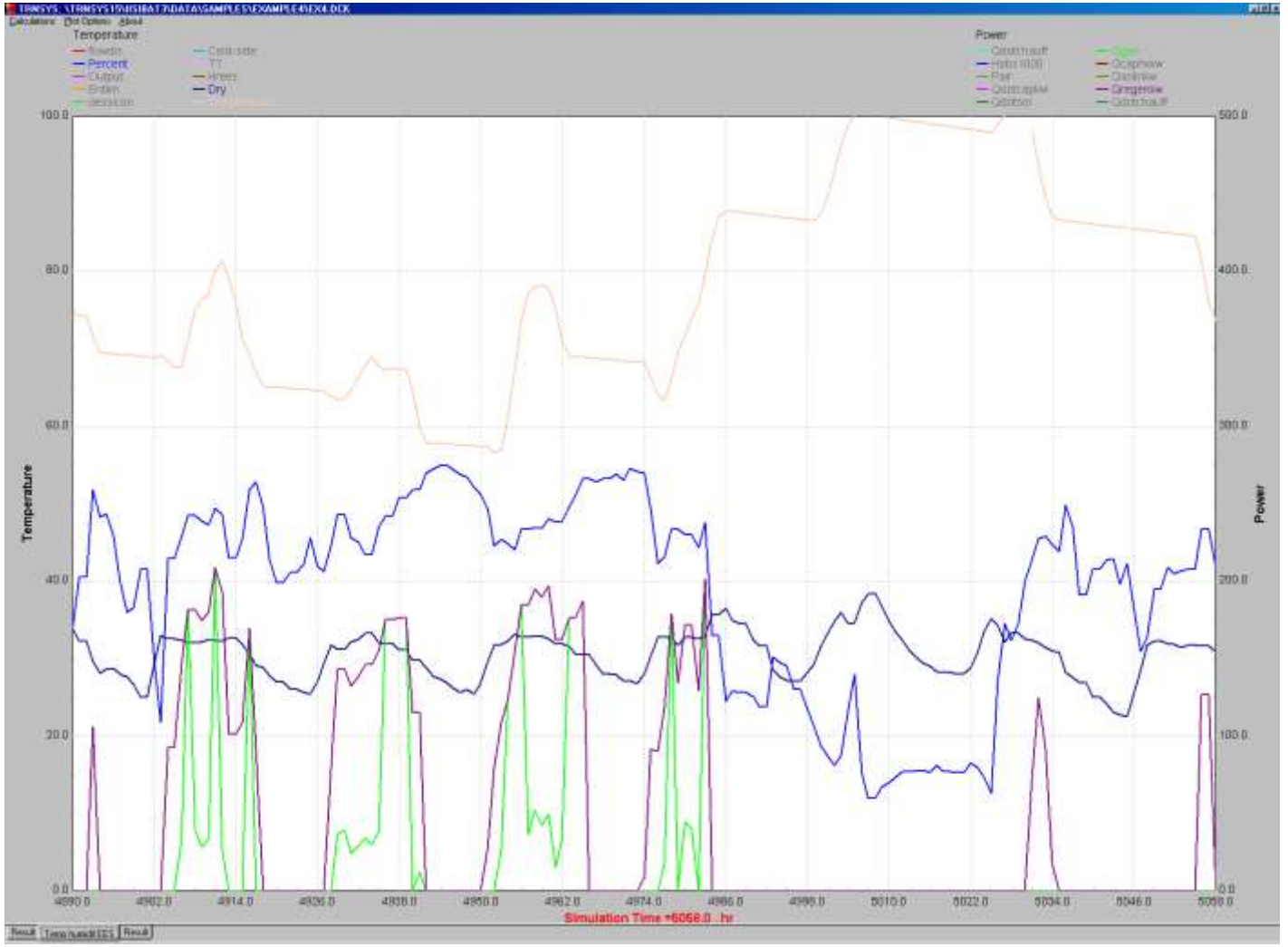
Effin'Art
The Art of Energy Efficiency

TRNSYS EES coupling IISIBAT



Effin'Art

The Art of Energy Efficiency



---------	Regeneration power supplied by auxiliary power from gas boiler
---------	Regeneration power (sum of solar + auxiliary)
---------	Solar storage temperature
---------	Ambient temperature
---------	Relative humidity

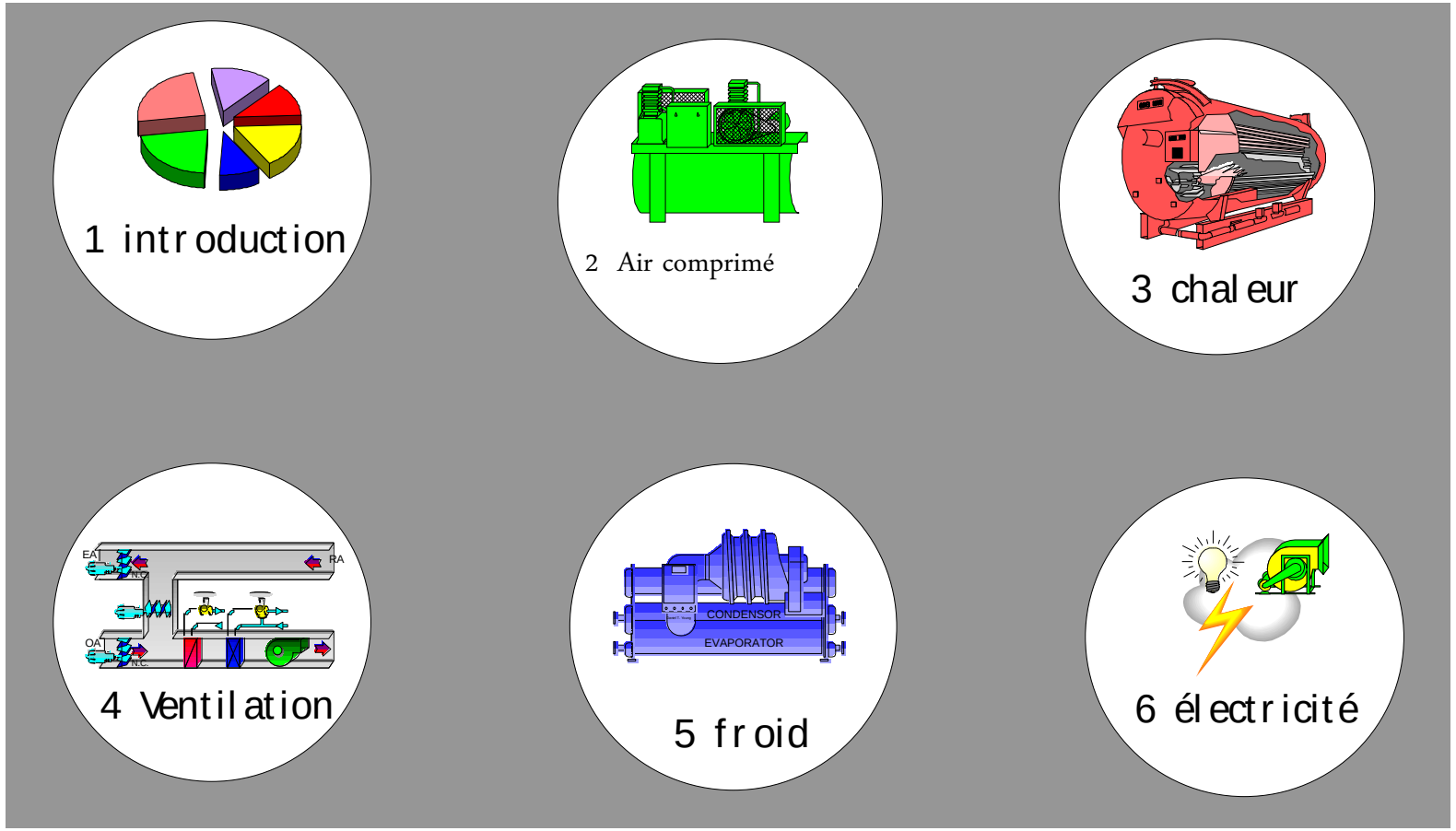
Effin'Art
The Art of Energy Efficiency

Conclusions

- TRNSYS-EES coupling is a functional option for quick small duration simulations when no TRNSYS routine is available
- Debate between algorithmic and equation based simulation is a wrong problem
  - Make use of best of both worlds
    - Robust simulation environment (TRNSYS)
    - Most flexible equation solving (EES)
- Question to ask before starting the work
  - Analyse if EES is a practical option (one unique project, or quick feasibility study)
  - Otherwise develop a specific TRNSYS type (routine projects)

Modules de cours

Energie 2000 Secteur industrie



Project in charge by P. Jaboyedoff when employed by Sorane

Groupement Nestlé Modèle énergétique

Nestlé Suisse SA :

- fabrique de Bâle
- fabrique de Broc
- fabrique de Konolfingen
- fabrique d'Orbe
- fabrique de Rorschach
- fabrique de Wangen

Nestlé Suisse SA, siège de Vevey

Nestec SA PTC Orbe

Nestec SA Vevey

CRN Nestec SA Lausanne

Nestlé PTC Konolfingen

Modérateur Pierre Jaboyedoff

Mandated by the Energy Agency when employed by Sorane

Effin'Art
The Art of Energy Efficiency

Swiss Federal Office for Energy
Energy use of office buildings

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE
Swiss Federal Office of Energy SFOE

- Analysis of the electrical consumption with break-up of 120 buildings
  - Classified in
    - Completely mechanically ventilated and cooled
    - Partly mechanically ventilation and/or cooled
    - No mechanical ventilation nor cooling
  - The simpler the better !!

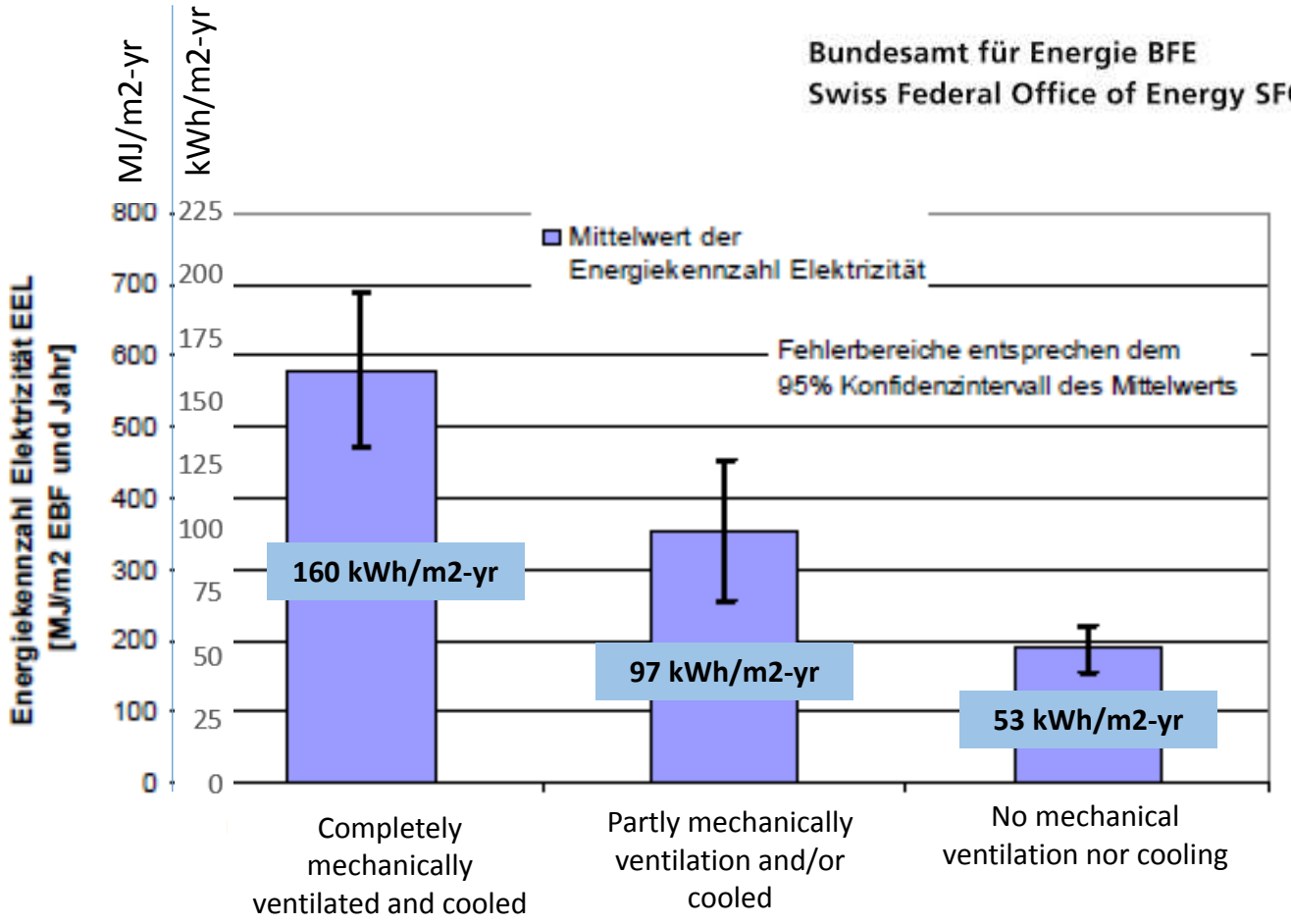


Abbildung 3: Energiekennzahl Elektrizität, Vergleich der Gebäudeausrüstung Lüftung /Klima (n = 120 Gebäude)

Project contribution performed by D. Aiulfi when employed by Sorane

Effin'Art
The Art of Energy Efficiency

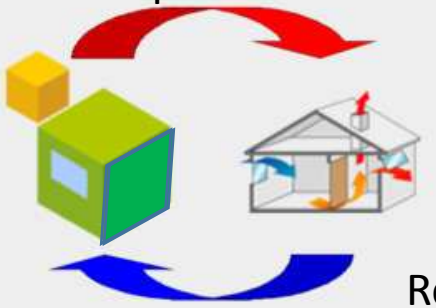
Approach followed: Simplicity by substituing walls in TRNSYS model for hygrothermal modelling

Wall·ACE

The objective of the Wall-ACE Project is to provide added value sustainable insulation solutions for the building market (2016-2019)

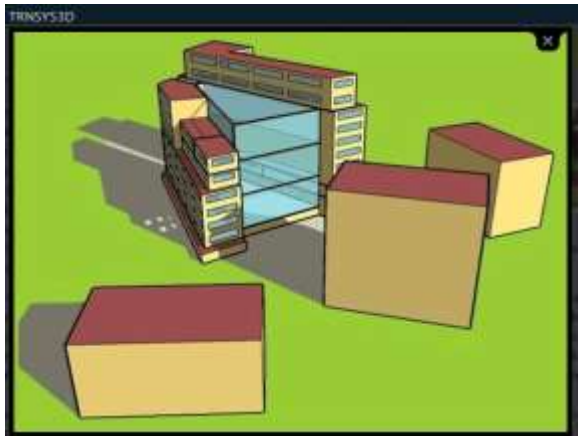
- Task 4.1
- Use an existing complete simulation environment (TRNSYS)
  - Allows to simulate one (or multiple zones)
  - Full building simulation radiant heat treansfer and including systems
  - Natural or mechanical ventilation strategies (TRNFLOW including humidity sources etc..)
  - Allows to replace transfer response walls with finite difference walls
  - Control of the node meshing
- Make a public domain application which can be used by a large number of planners, manufacturers
- Method
  - Develop a simulation model which is in between Wufi like softwares and Glaser method
  - Allows to integrate the Glaser method
  - Gives intermediate results
- Development and integration of an implicite finite difference scheme to replace one or more walls of the Type 56 (multi-zone building of TRNSYS)
  - Checking and validation of simple cases for thermal behaviour
  - Integration of Glaser modelling

Remove a transfer reponse wall



Replace it by a finite difference wall

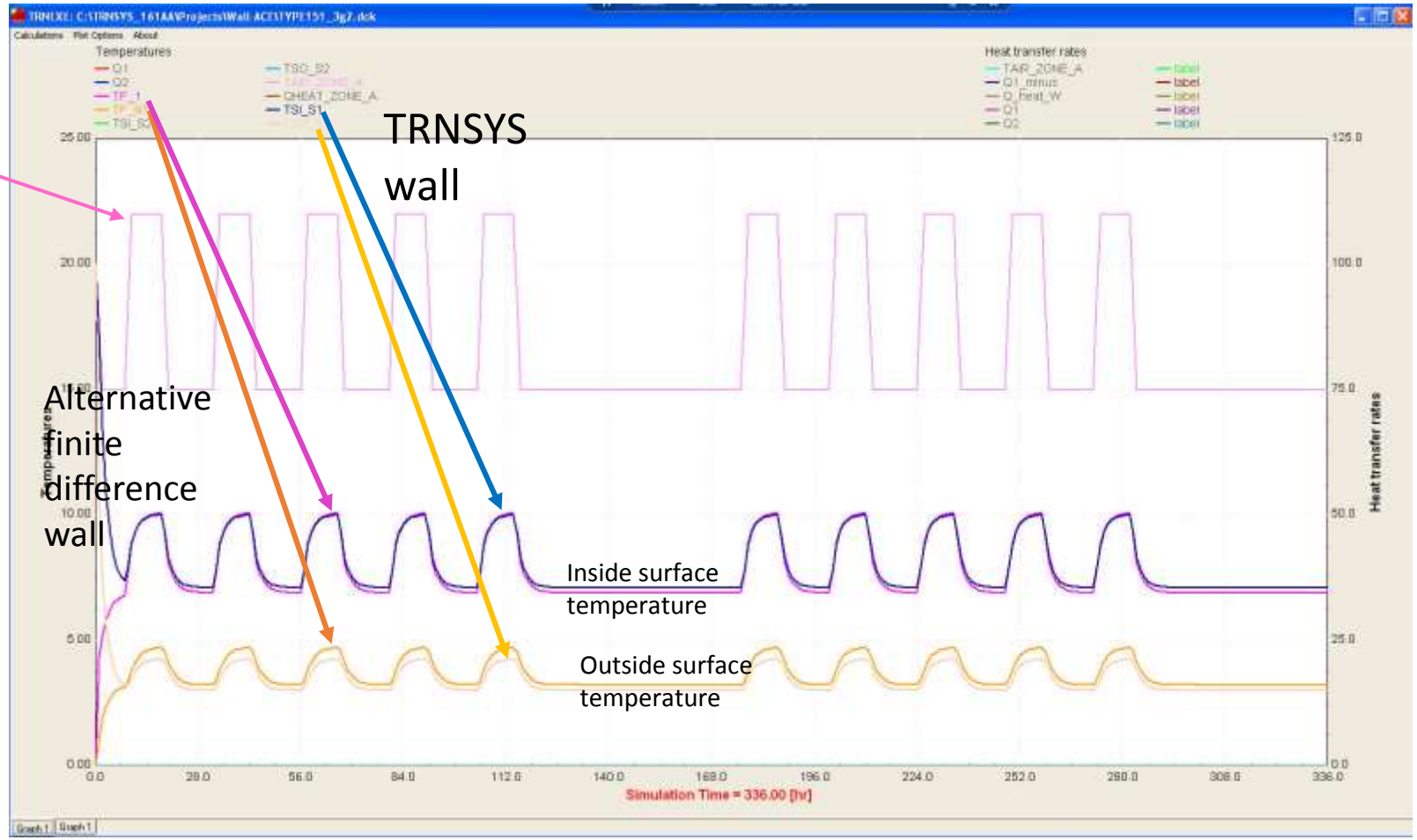
TRNSYS → TRNSED



Effin'Art
The Art of Energy Efficiency

Pre-validation in temperature behaviour

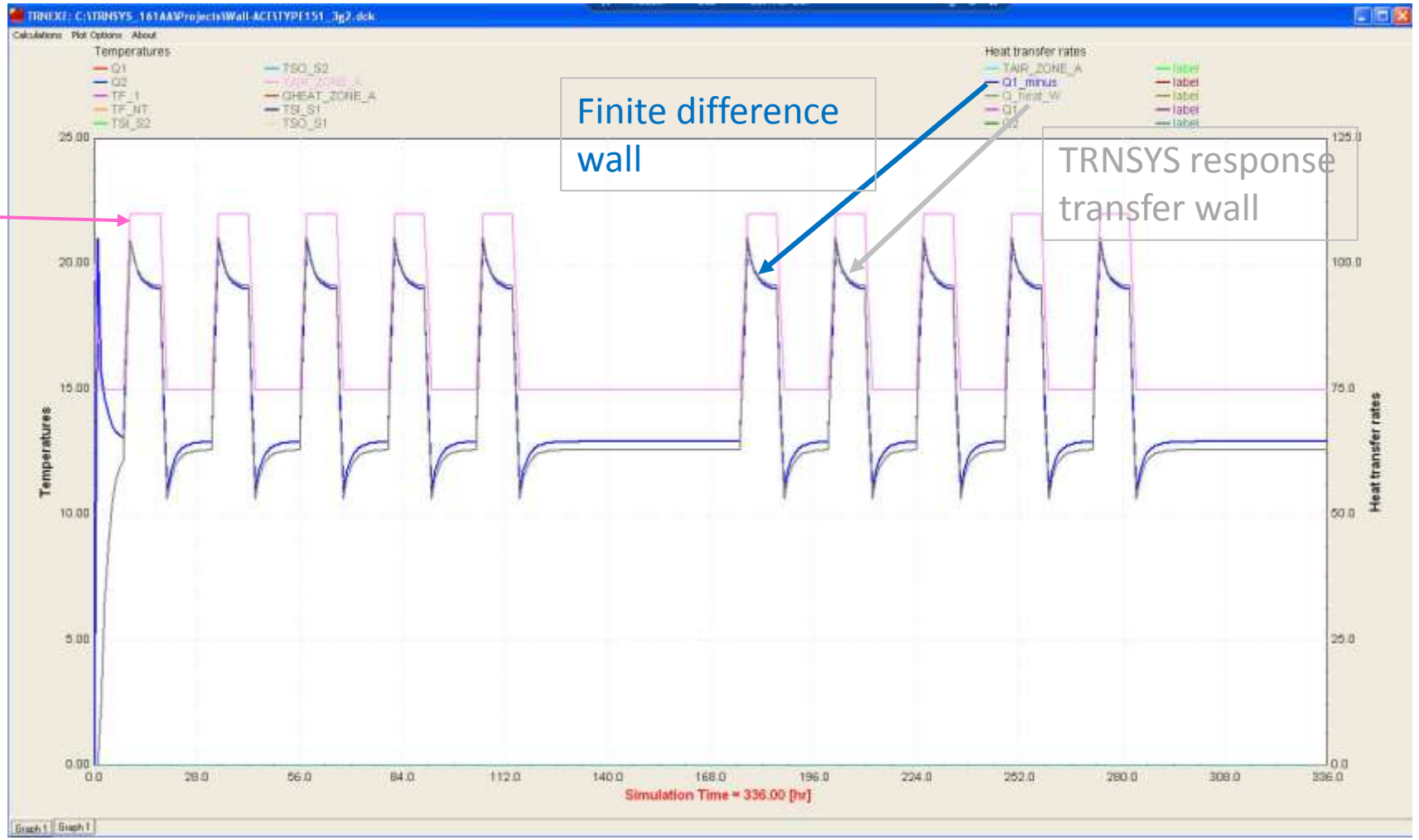
- Day and night set-point (22-15°C)
- Comparison of inside and outside surface temperature



Effin'Art
The Art of Energy Efficiency

Pre-validation in heat balance

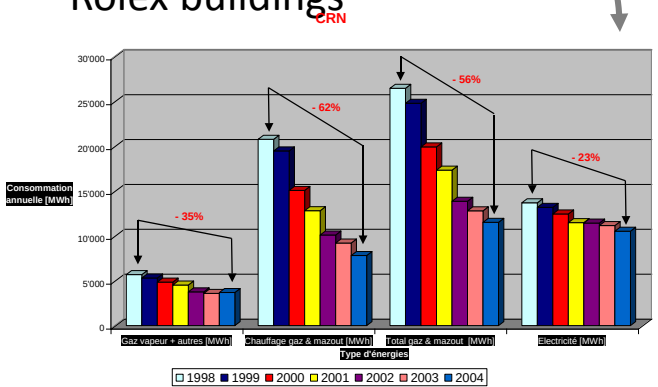
- Day and night set-point (22-15°C)



Effin'Art
The Art of Energy Efficiency

Some related projects/experiences in Europe

- Some projects
  - BC EPFL
  - Swiss Federal Office for Statistics buildings, Neuchatel, Switzerland
    - One of lowest measured specific energy demand in Europe
  - WIPO extension Geneva
    - Very complex architectural expression
  - Watch Factory
    - Very tight specifications
  - Rolex Learning Center, Lausanne
    - Very complex architectural expression
  - Rehabilitation and extension of a large office building in Paris
    - Integrate natural ventilation
- Energy audit, optimisation
  - Research Centre Nestlé
  - University hospital Lausanne
  - Rolex buildings

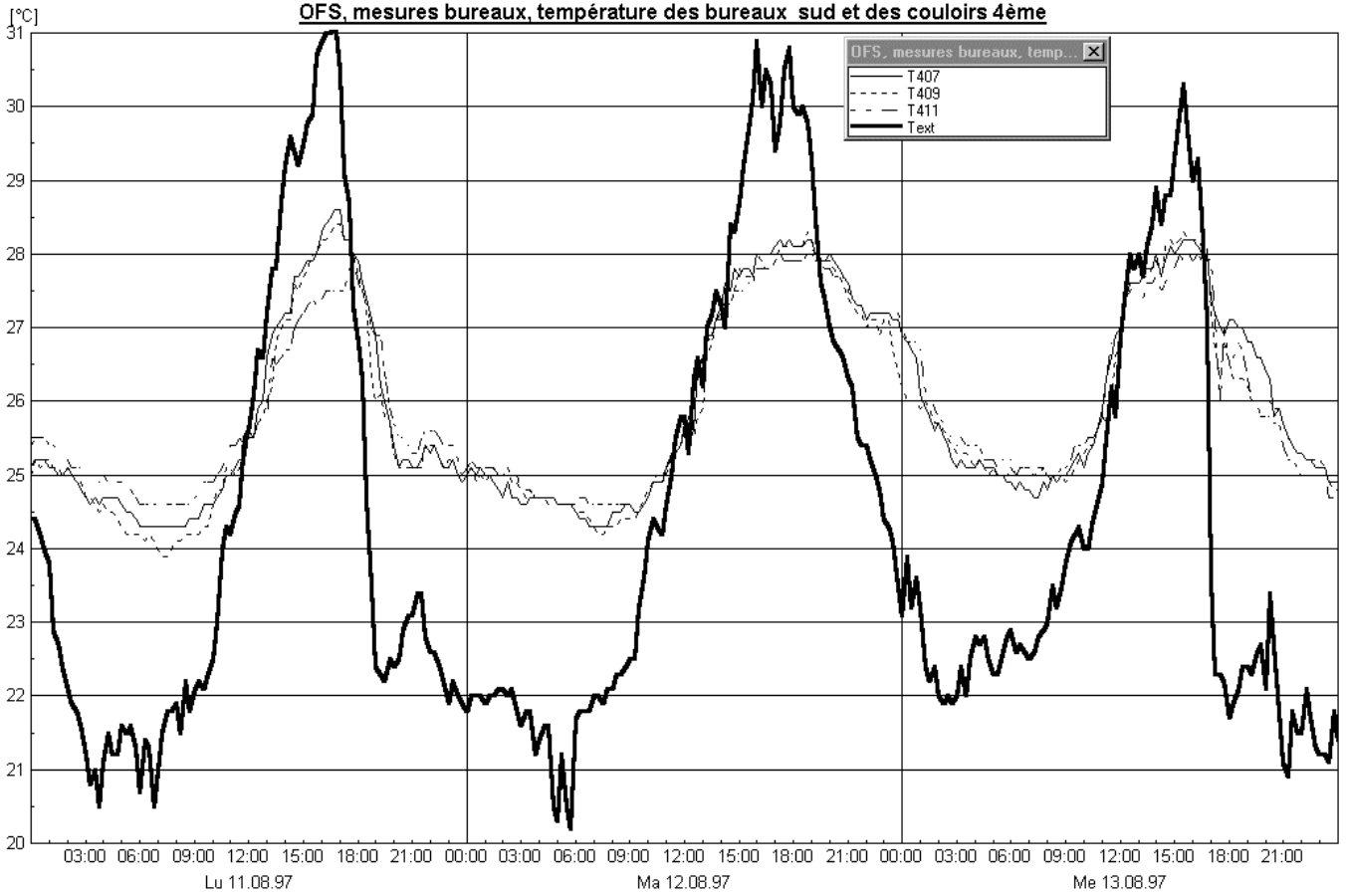


Project performed by DA, DC, PJ when employed by Sorane

Effin'Art
The Art of Energy Efficiency

OFS measurement of temperature in two offices with simulated internal gains before occupation

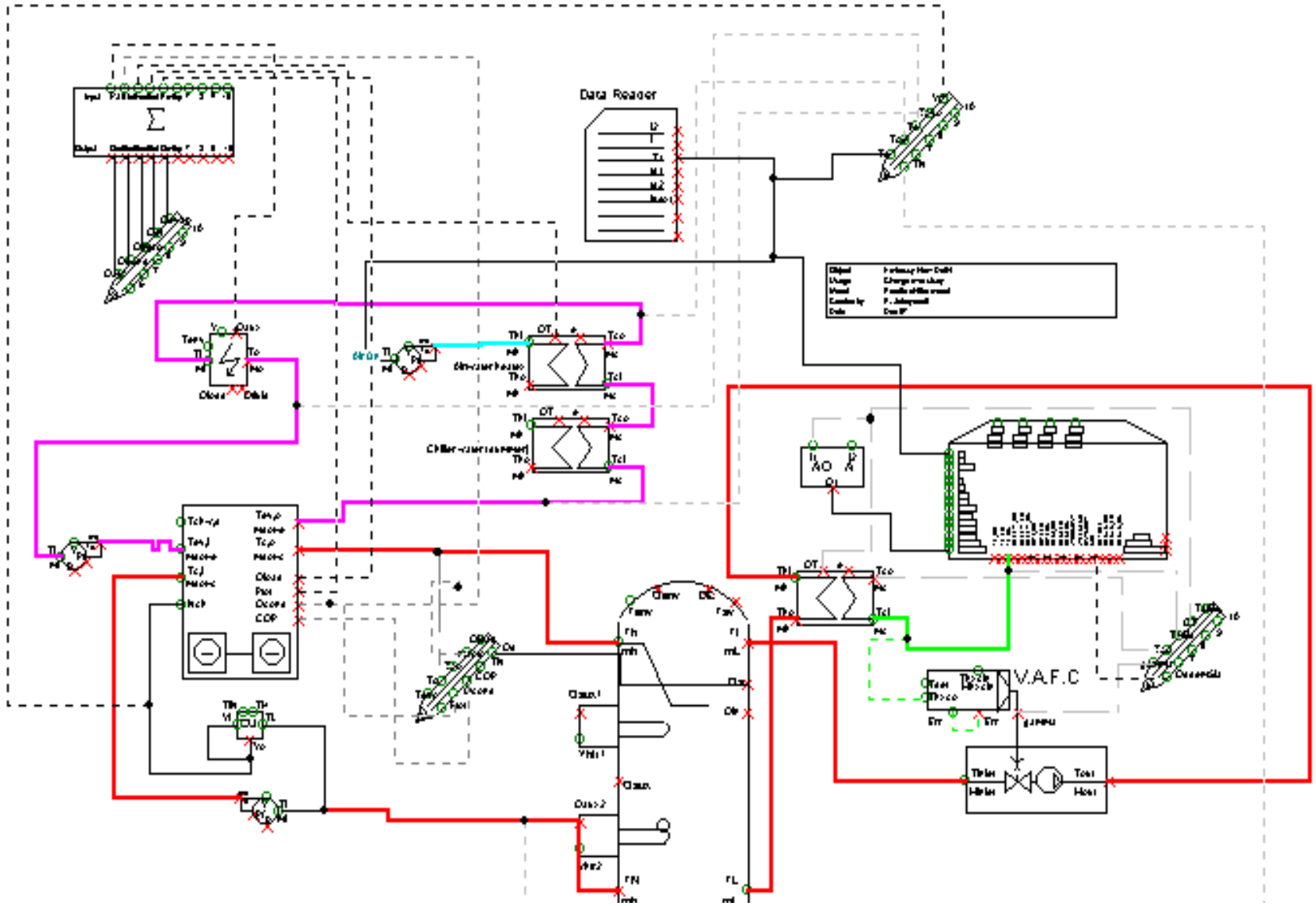
- Confirmation of the simulated results (< 28°C) at 4th floor
- High inertia
  - Only part of the ceiling covered with acoustic damping plate
- With external fabric awnings lowered when the sun is hitting the glazing
- Night natural ventilation



Work performed by DA when employed by Sorane

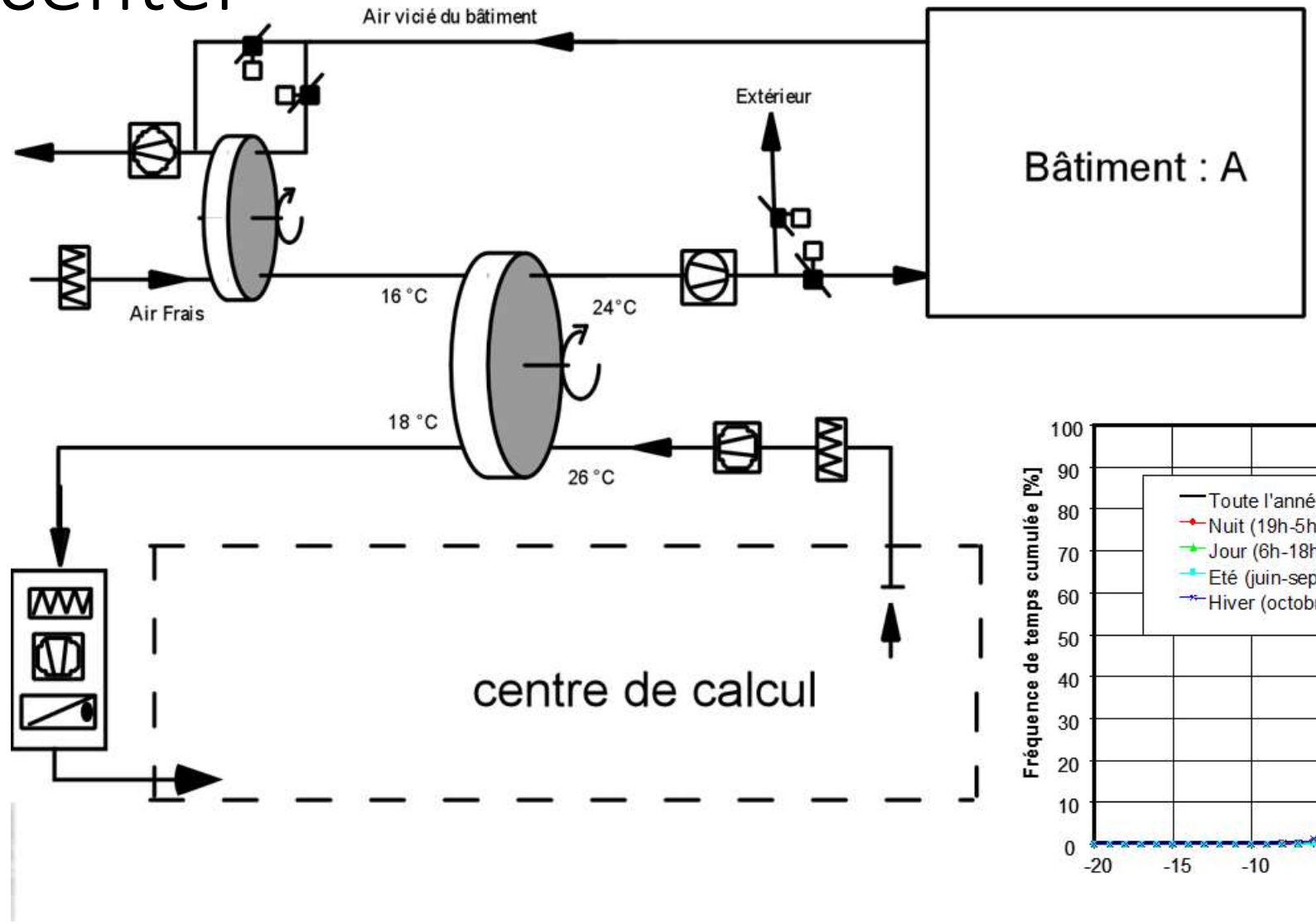
Effin'Art
The Art of Energy Efficiency

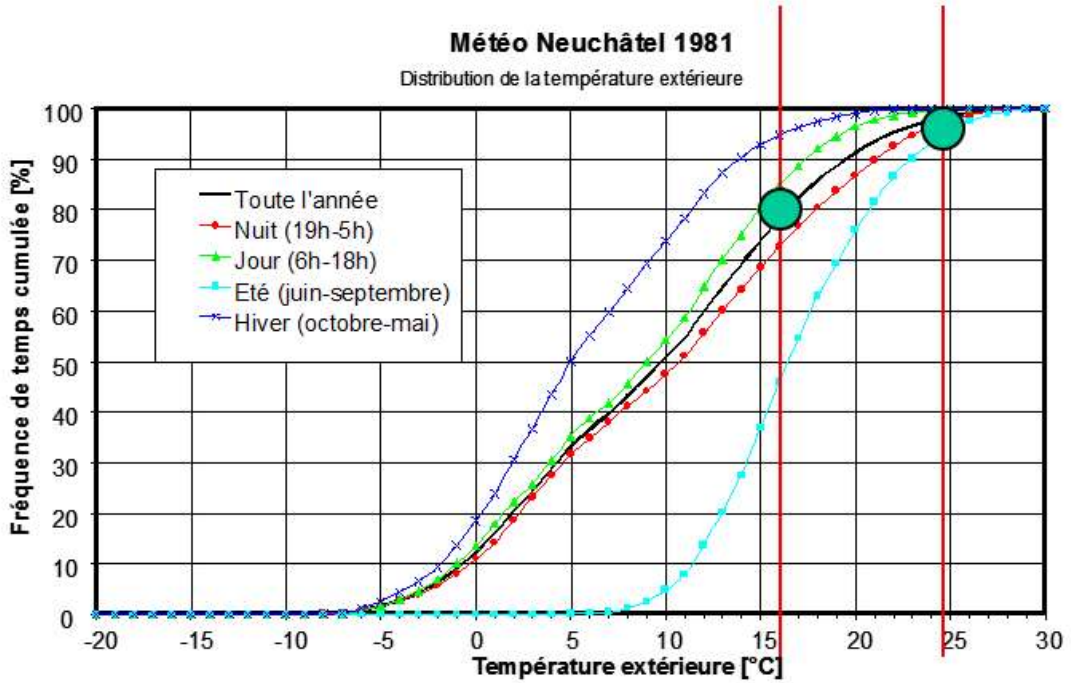
TRNSYS model for the OFS building



Effin'Art
The Art of Energy Efficiency

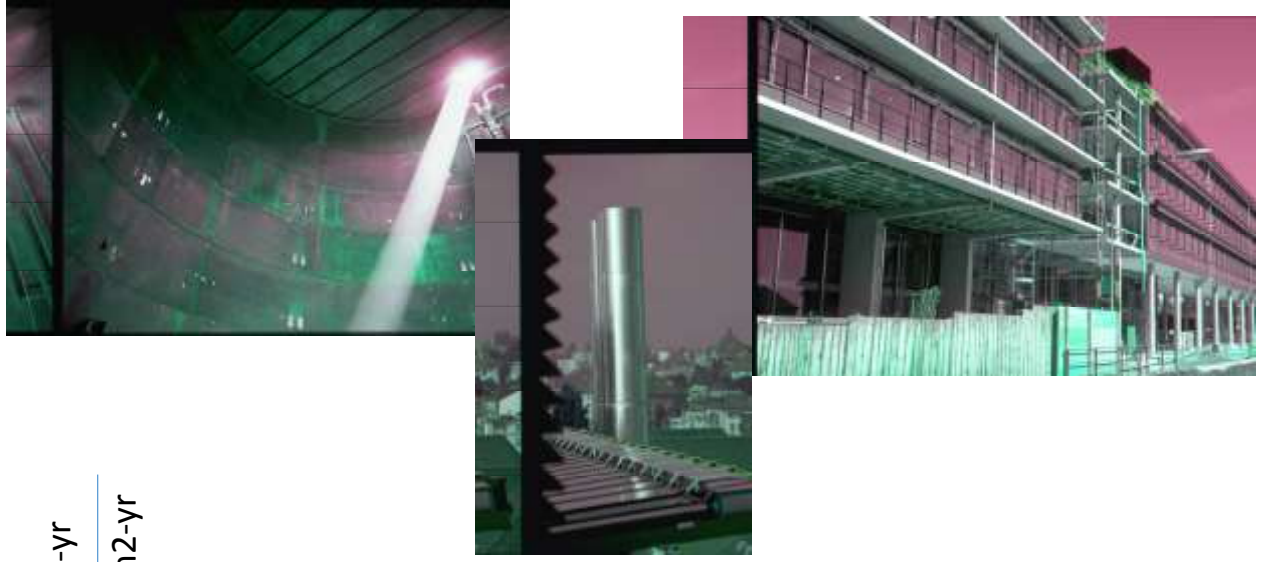
Free-cooling and heat recovery of the data center

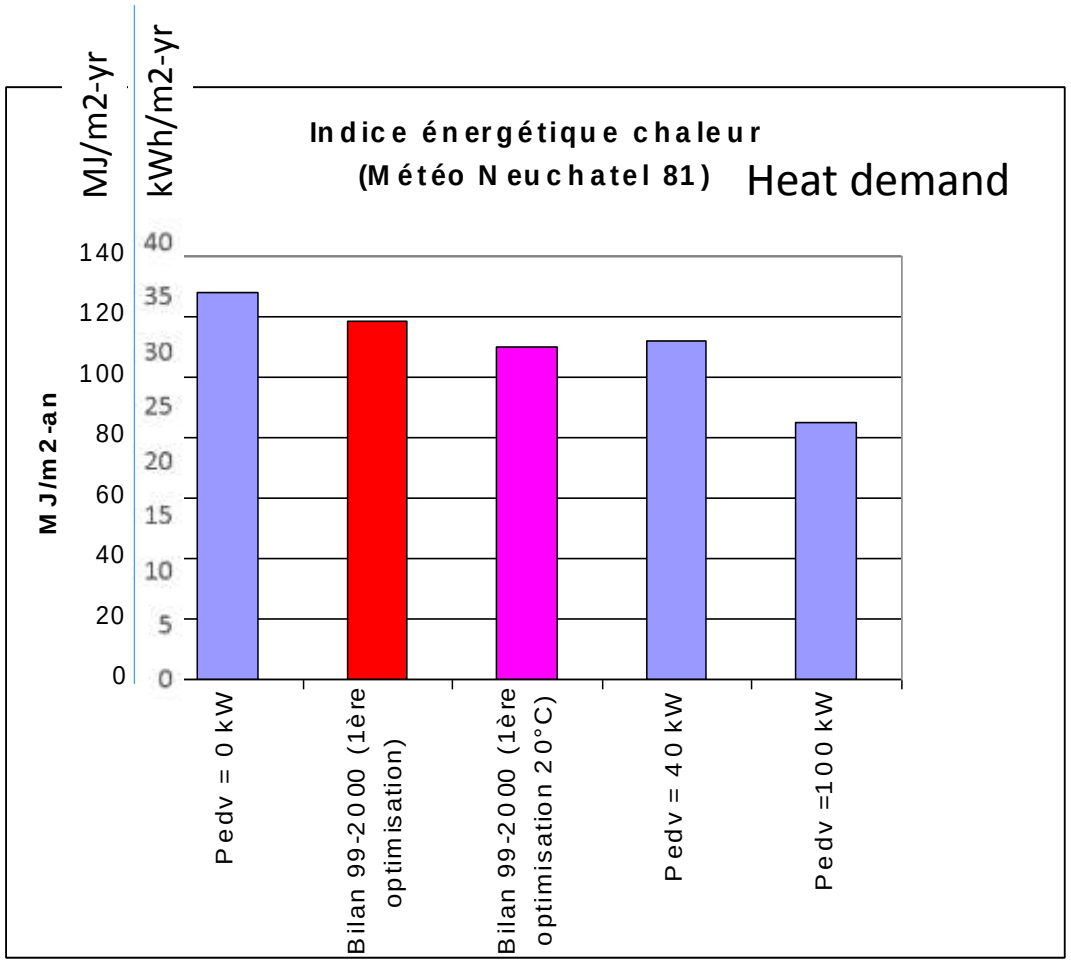


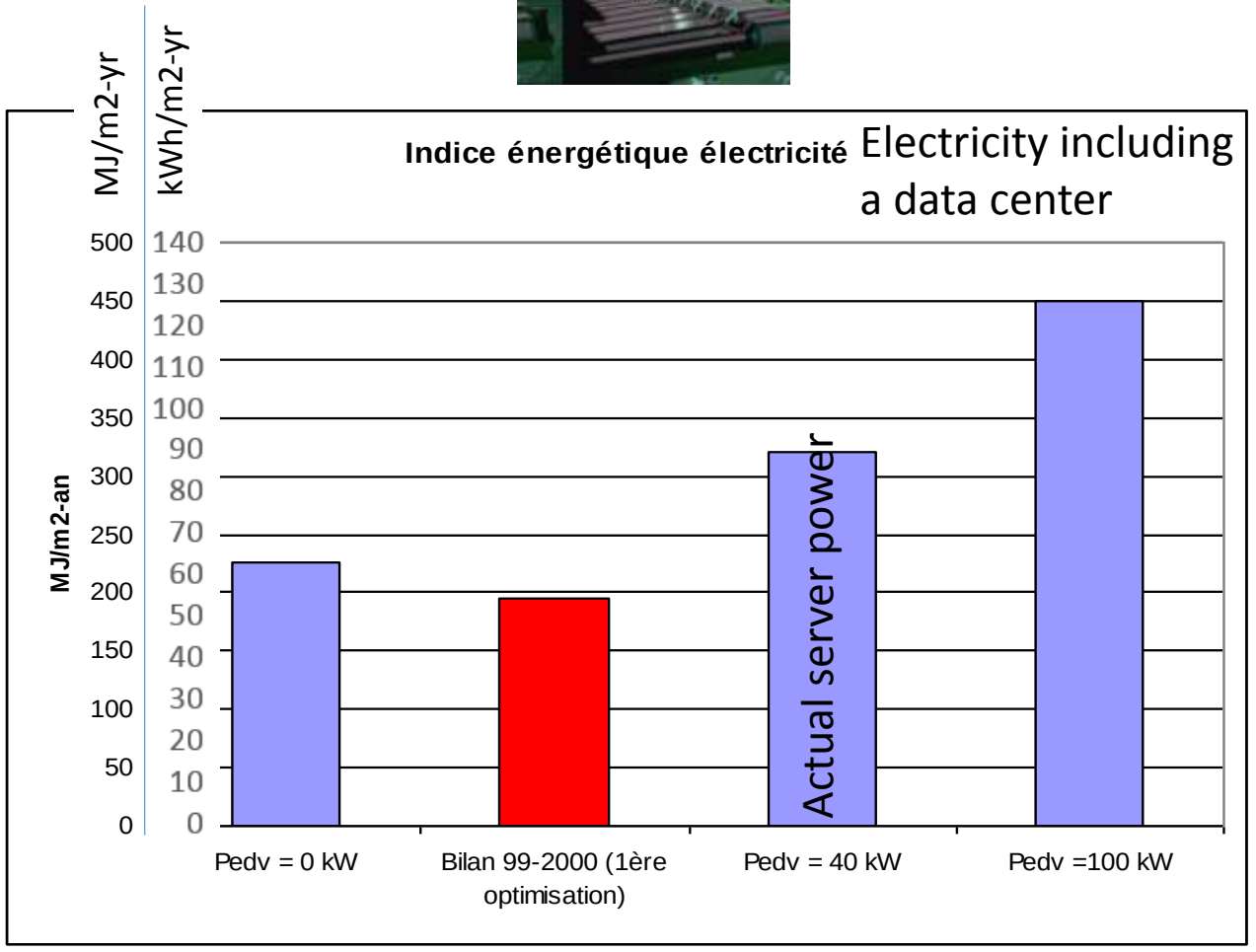


Effin'Art
The Art of Energy Efficiency

OFS







Effin'Art
The Art of Energy Efficiency

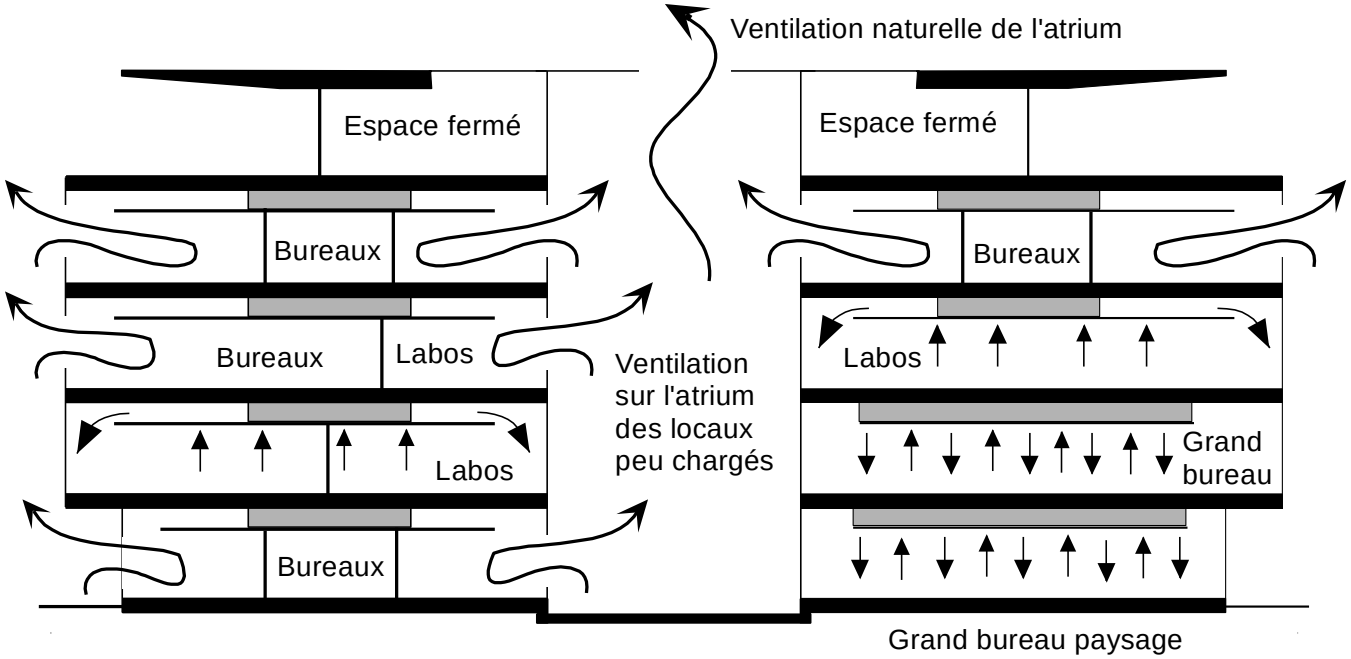
Building of Communication; EPF, Lausanne

- Natural Ventilation but the internal classrooms
- External retractable lamella blinds (two angle zones)
  - Optimise daylight and keeps a very low SHGC value
- Daylighting
- Inertia
- Simplicity

Project development performed by DC and DA when employed by Sorane

Effin'Art
The Art of Energy Efficiency

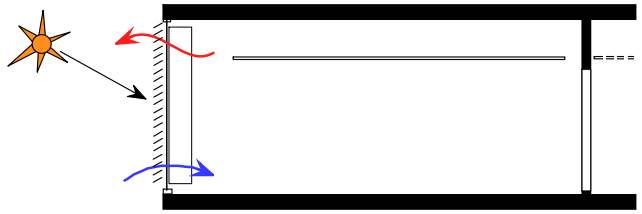
EPFL-BATIMENT SYSTEMES DE COMMUNICATION



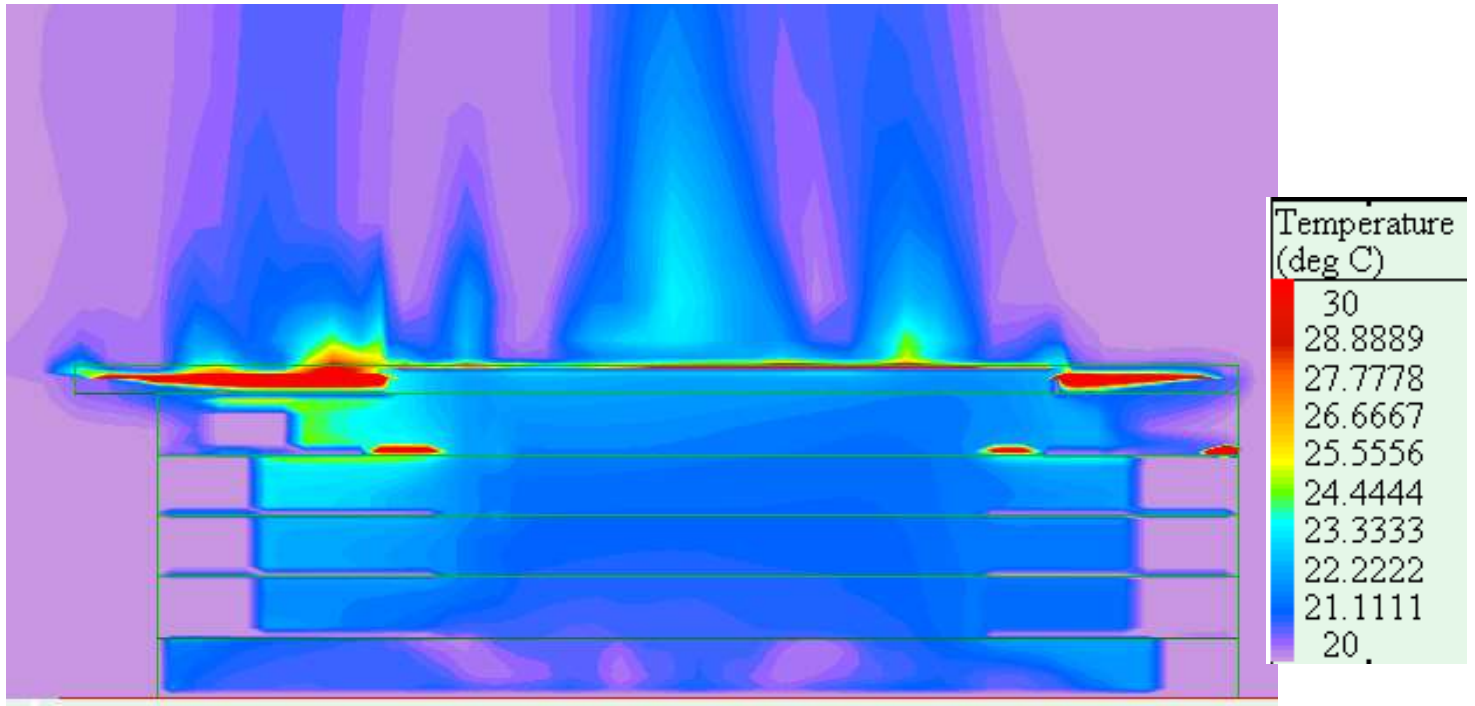
Grands bureaux paysages clos:
ventilation naturelle ou mécanique de l'atrium

BC: Bureaux

- Insulated natural ventilation vent on the facade behind a rain protection grille
- Opened false ceiling to access building mass (concrete slab)



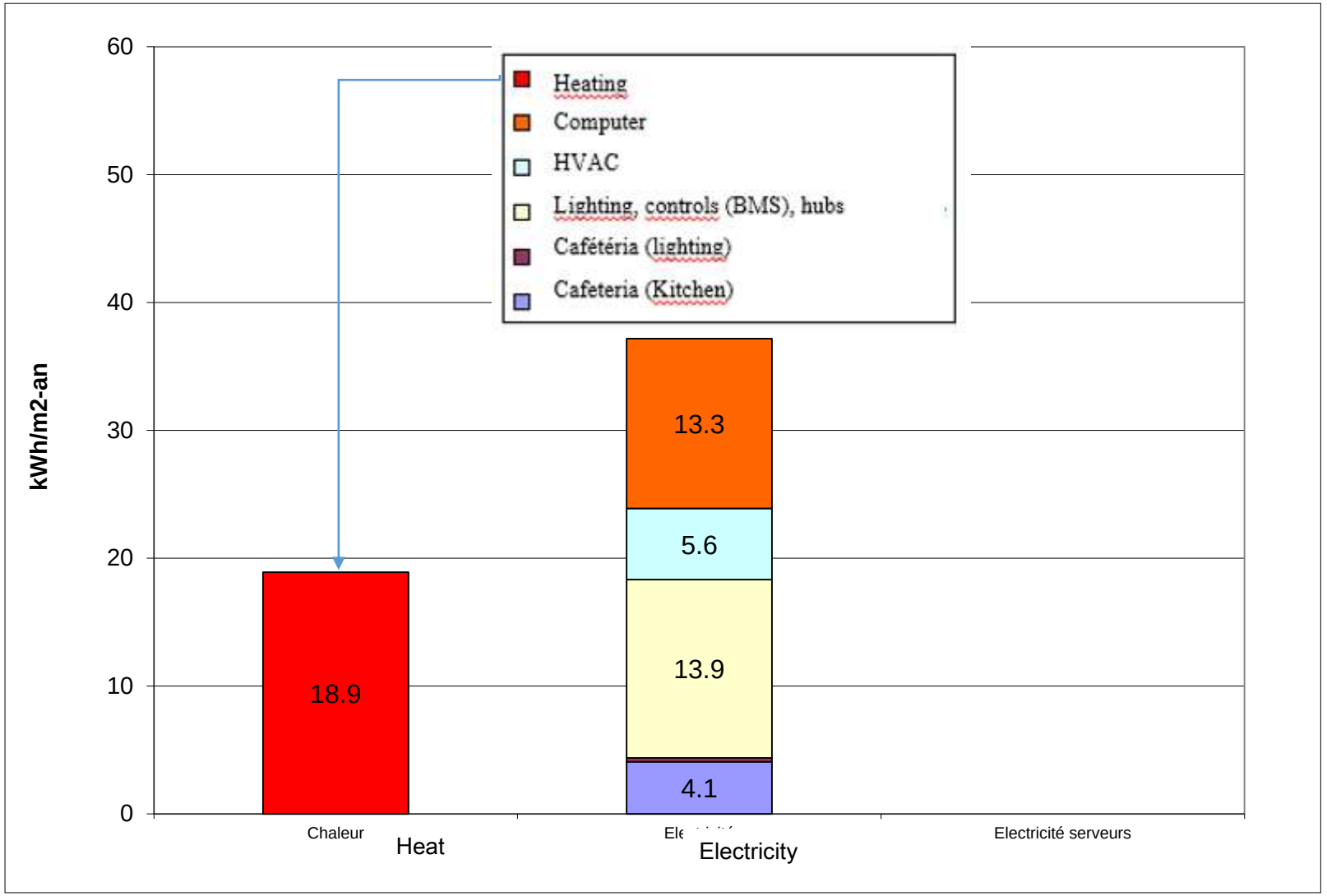
Atrium: contrôle du climat estival



Champs des températures

Effin'Art
The Art of Energy Efficiency

BC EPFL: Measured energy performance index



Effin'Art
The Art of Energy Efficiency

Administrative building at Ittigen (near Bern)

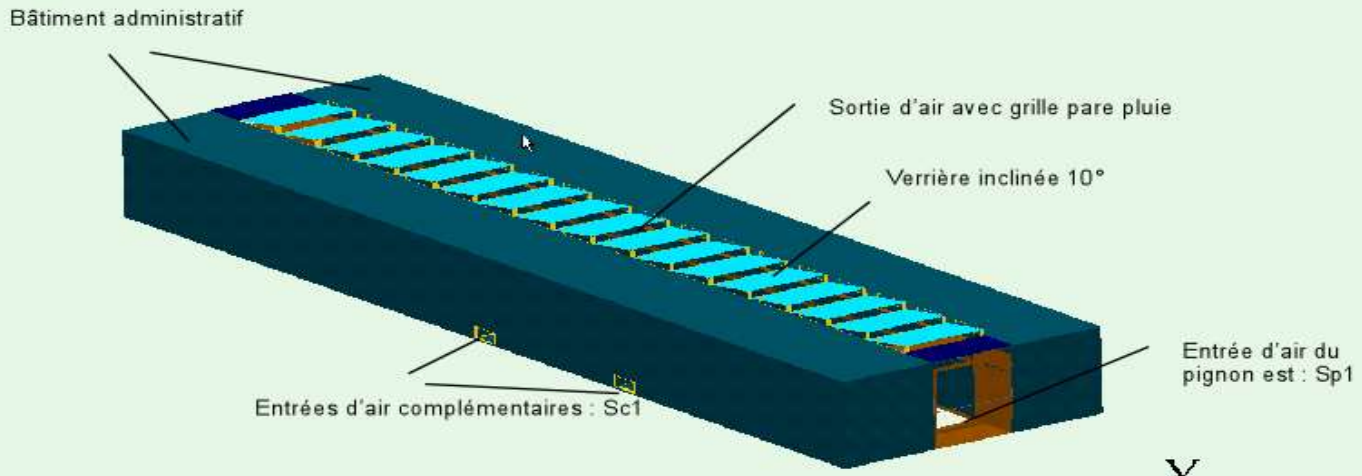
Issues to solve

- Overheating in summer in the atrium
- Overheating of offices facing the atrium
- Overheating in the offices at the top floor

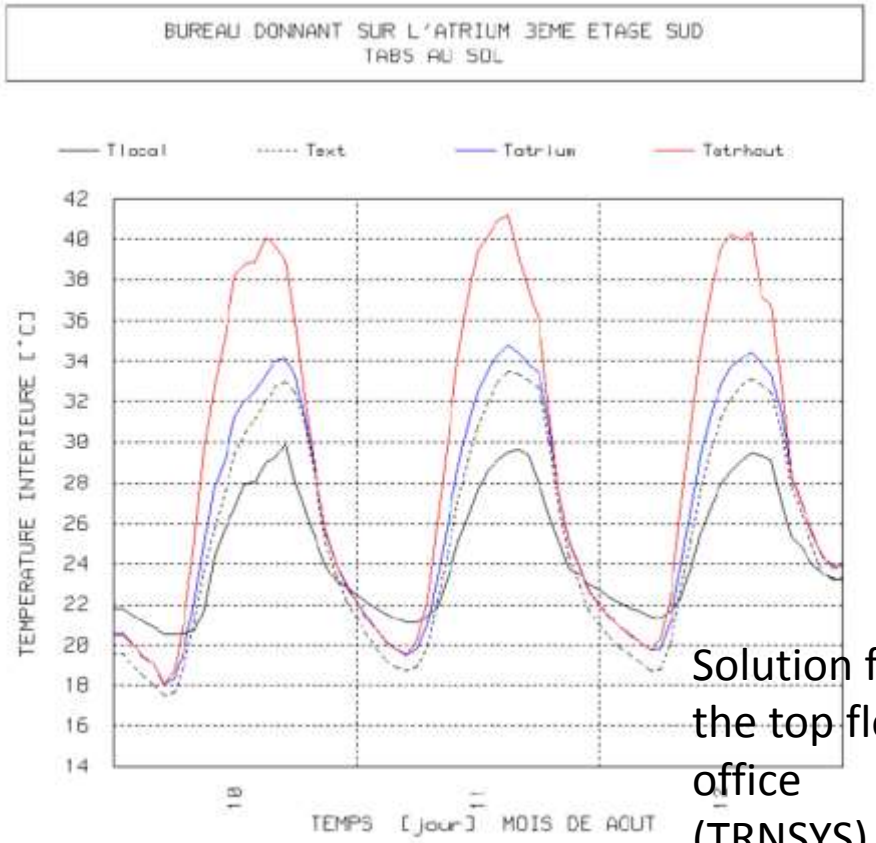
Ittigen Areal / Worbla ost : Bâtiment VG
Modèle CFD

View: 3D

27'000 m2



Project performed by D. Aiulfi when employed by Sorane



Solution for the top floor office (TRNSYS)

Administrative building at Ittigen (near Bern)

Effin'Art
The Art of Energy Efficiency

Raise the roof by 2.5 m

- reduce the hot zone on top
- design a cross natural ventilation on top floor offices
- No cooling in the building, only the top floor offices equipped with radiant cooling with borehole source
- Measured consumption
  - Gas : 10 kWh/m2-yr
  - Electricity : 62 kWh/m2-yr

Ittigen Areal / Worbla Ost
Bâtiment VG

Ventilation des bureaux et de l'atrium

Variante 3 :

Toiture de base selon plans architectes mais surélevée de 2.5 m

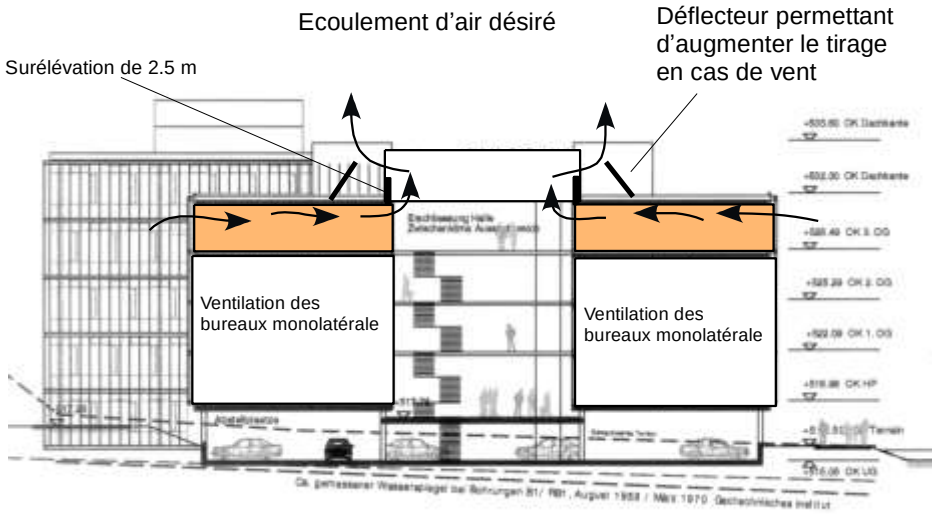
Ventilation traversante du 3 éme étage NORD-EST ET SUD-OUEST

Ventilation monolatérale pour les rez , 1er et le 2ème étage

Entrées d'air rez :

-Pignons : 2x22 m2 (100% ouvert)

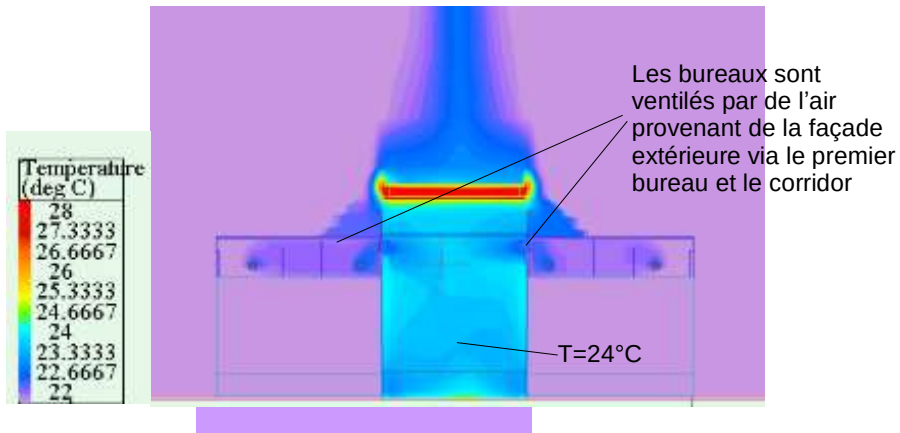
-Latérales : 4x6.8 m2 (coefficient de résistance de 7)



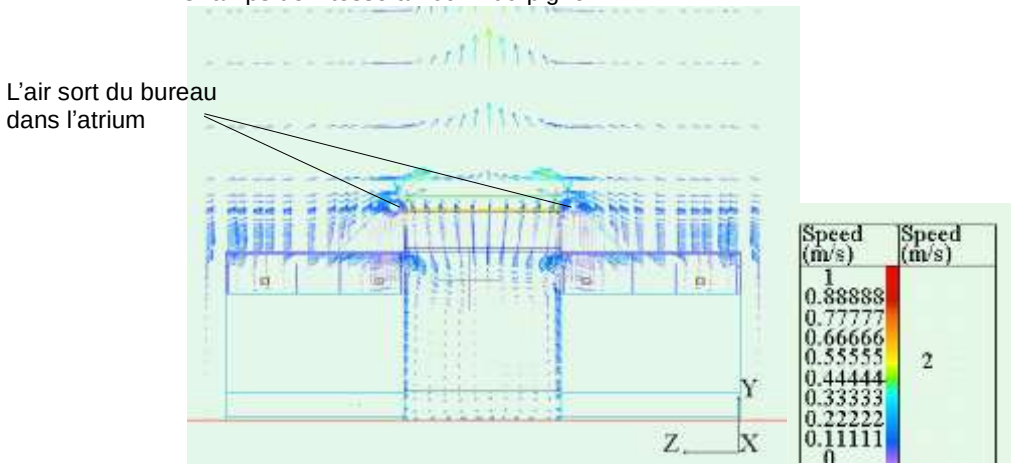
Ventilation traversante des bureaux du dernier étage par tirage thermique à travers l'atrium

Résultats CFD sans vent

Champs de température à 160 m du pignon



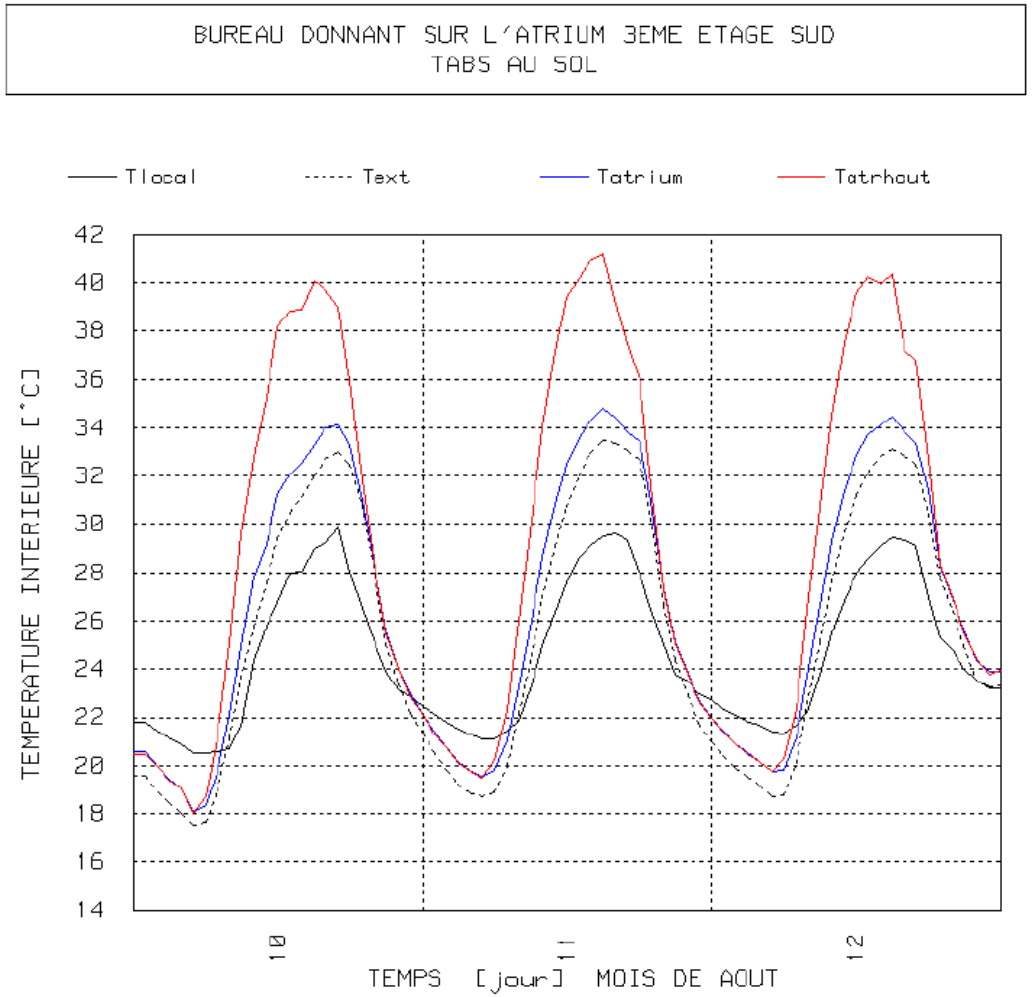
Champs de vitesse à 160 m du pignon



Effin'Art
The Art of Energy Efficiency

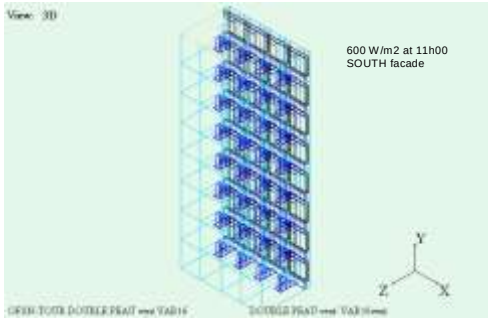
Simulation thermique dynamique des batiments

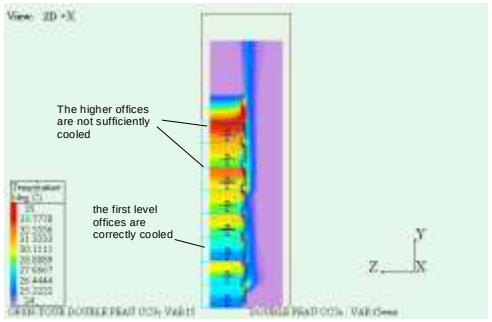
- Prise en compte des aspects de stratification par le couplage thermo-aéraulique



Effin'Art
The Art of Energy Efficiency

Swiss Federal Office for Statistics Tower: Example of applications of sophisticated tools during the integrated design process





➢**Paradox of high energy performance energy efficient buildings and systems:**

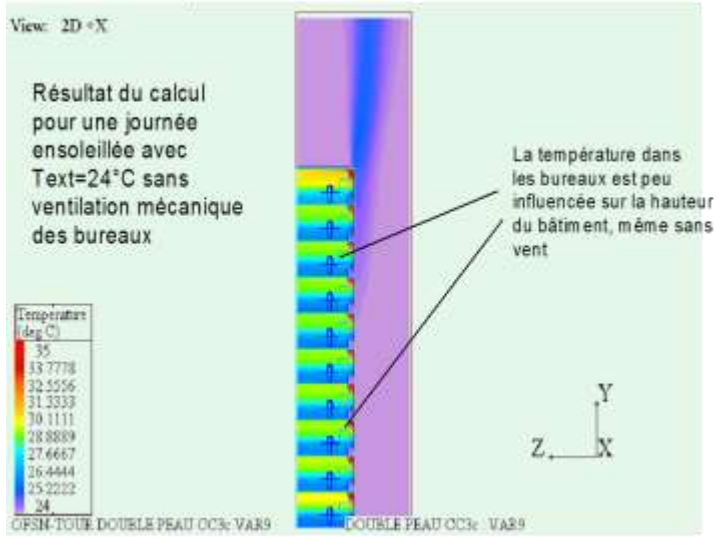
"The simpler and more bioclimatic the buildings are, the more complex the design process is"

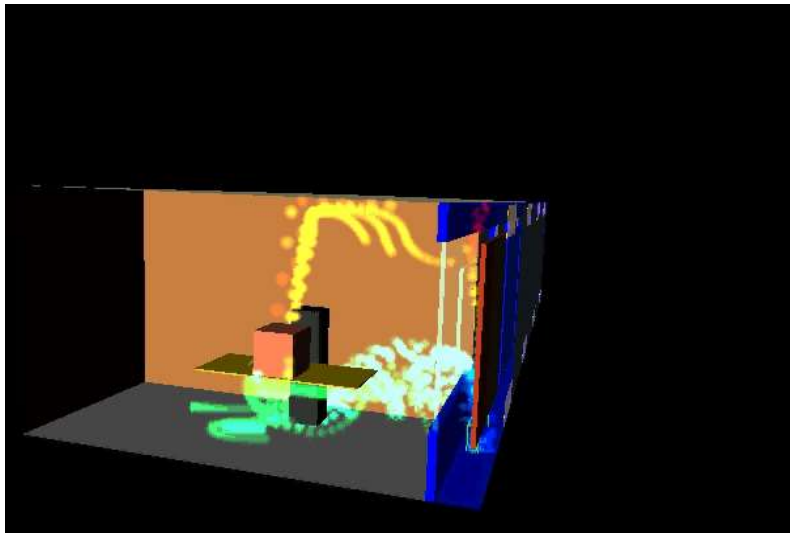
✓ *More sophisticated design tools needed*

✓ *Systemic analysis"*

Example:

- *Natural and hybride ventilation systems*
- *Adiabatic cooling*



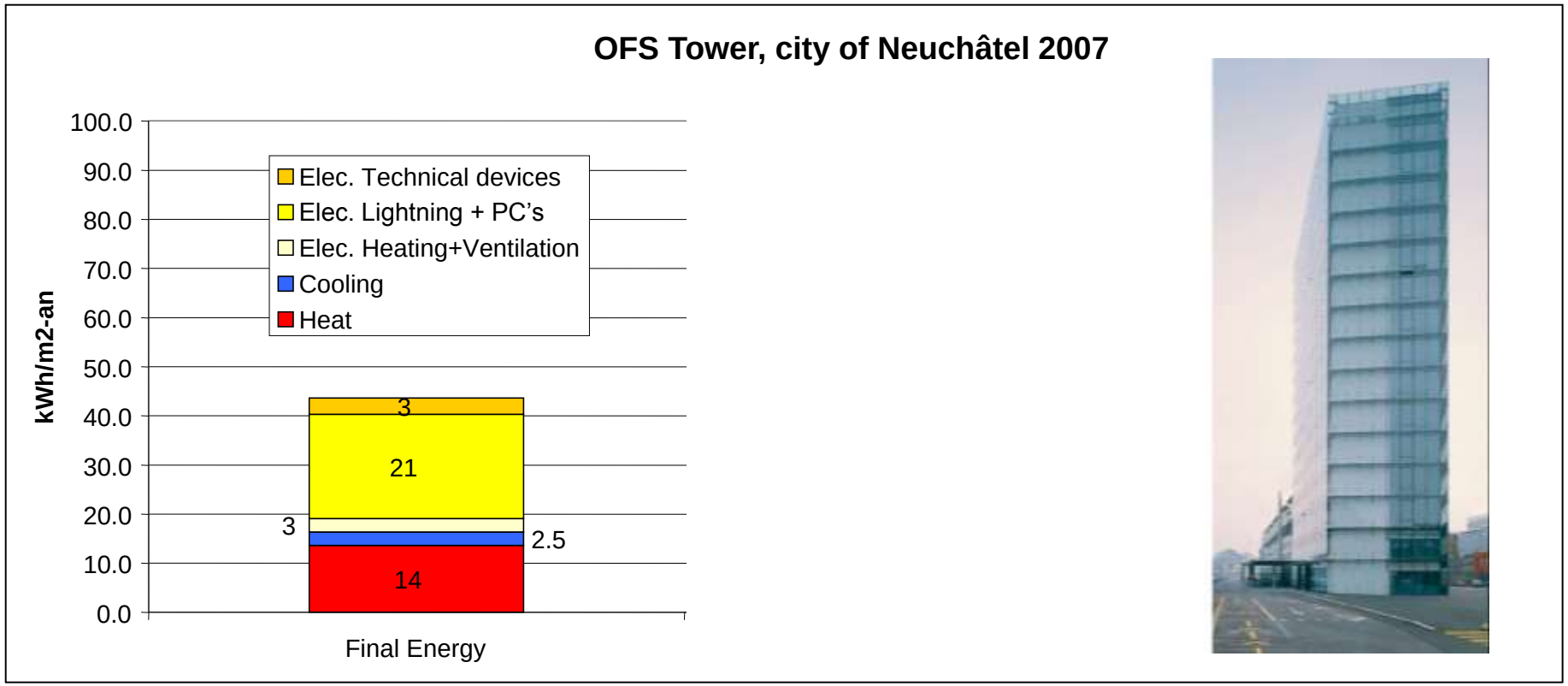


Project in charge D. Aiulfi when employed by Sorane

Effin'Art
The Art of Energy Efficiency

Energy Performance index of an existing tower

- Measured Energy Balance (Final Energy: 2007)
  - Final use energy (metering) : 43 kWh/m2-yr



Effin'Art
The Art of Energy Efficiency

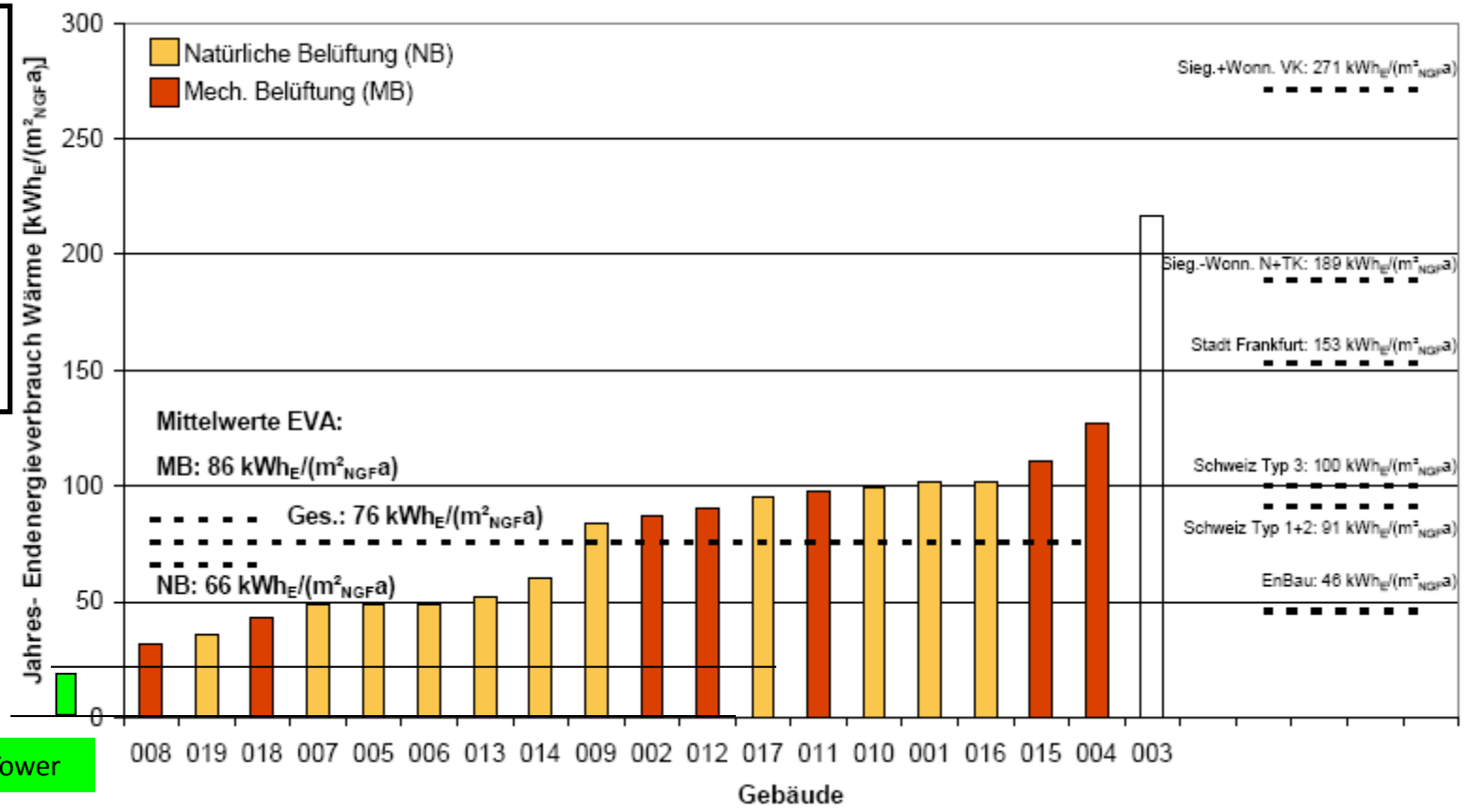
Comparison with EVA Study (Germany)

TU BRAUNSCHWEIG · INSTITUT FÜR GEBÄUDE- UND SOLARTECHNIK

Prof. Dr.-Ing. M. N. Fisch

EVA

Evaluierung von Energie-konzepten



Swiss Federal Office Tower

Effin'Art
The Art of Energy Efficiency

Total electricity consumption

EVA

Evaluierung von Energie-konzepten

TU BRAUNSCHWEIG · INSTITUT FÜR GEBÄUDE- UND SOLARTECHNIK
Prof. Dr.-Ing. M. N. Fisch

300

Average modern commercial building India
300 kWh/m2-yr electricity

250

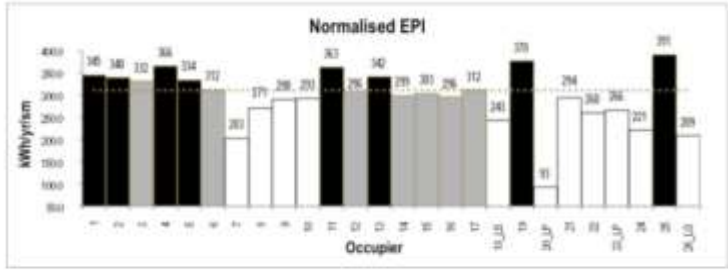
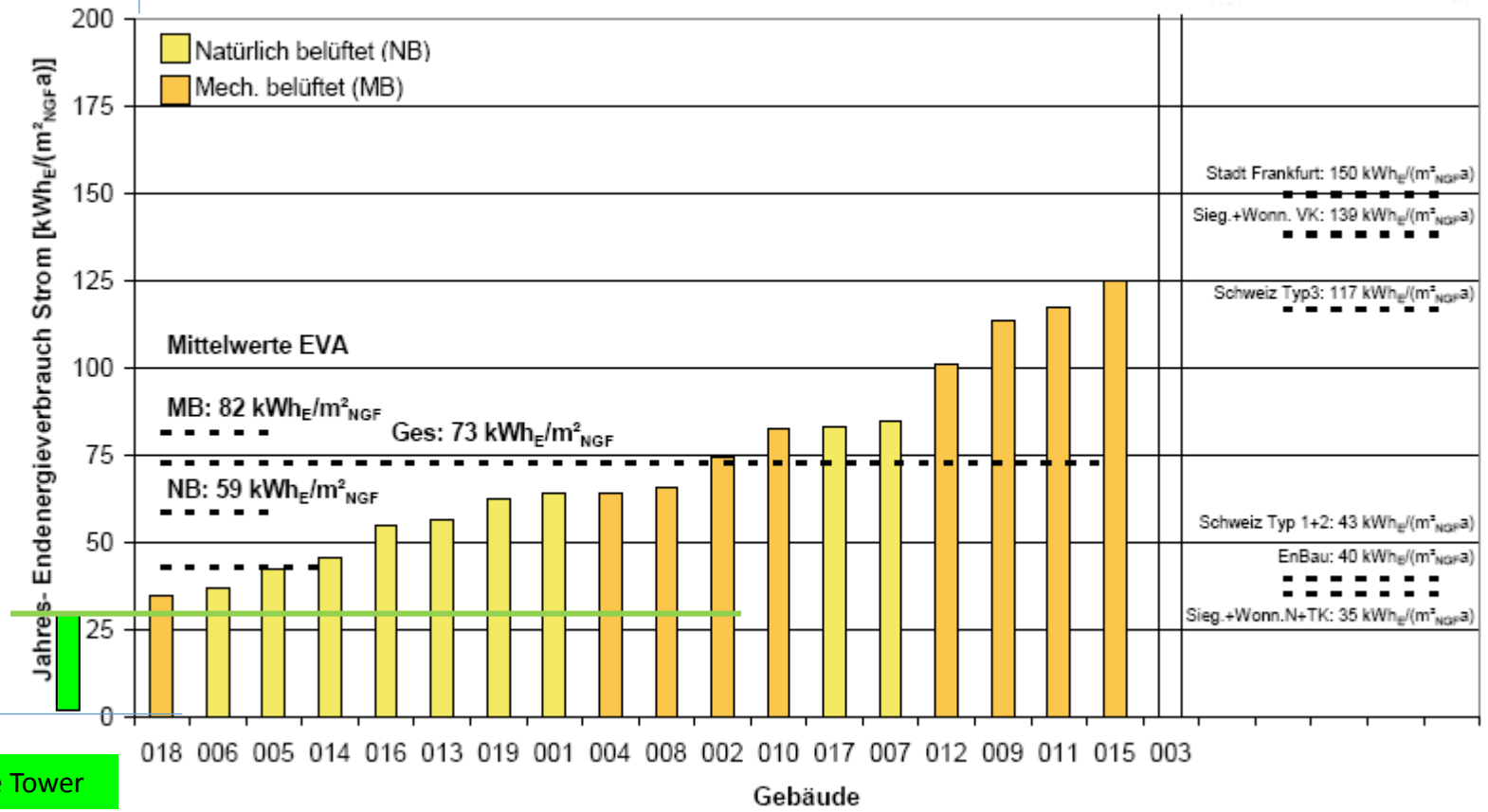


Figure 1: Normalised EPI for each facility



Swiss Federal Office Tower

Effin'Art
The Art of Energy Efficiency

Large watch manufacturer high performance building envelope, process integration for heat recovery and cooling

- https://www.minergie.ch/fr/batiments/details/?gid=BE-2214

BE-2214

Minergie, 2013, 2504 Biel/Bienne

Project in charge P. Jaboyedoff when employed by Sorane then since 2014 at Effin'Art

Effin'Art
The Art of Energy Efficiency

Process integration for high energy efficiency

- Concept
  - Low temperature heating (< 35 °C)
  - Gliding chilled water temperature , different groups with free-cooling Höhe Effizienz Wärmeruckgewinnung der Lüftungsanlagen
  - Free-cooling and heat recovery from the machining process (cooling water temperature level increased from 10-14 °C up to 18-24 °C)
  - Heat recovery from the high efficiency turbo air Zusatz
  - High temperature process heat supplied by pellets boilers
- Measured results
  - Practically no gas consumption (<5 kWh/m2-yr)
  - Peak heating demand ~ 10 W/m2
  - Peak electrical power for cooling ~ 10 W/m2

B) Hybrid cooling towers (Jaeggi) Free-cooling

C) High performance chillers (magnetic turbo)

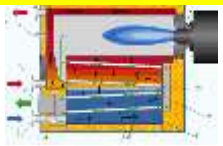
G) Pelletsboiler → high temperature process heating (galavnoplasty)

H) Condensing gasboiler →only as backup

Free-cooling

Evacuation de chaleur des condenseurs

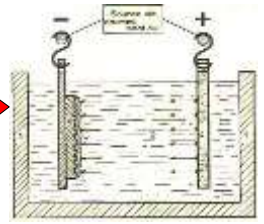
B) Refroidisseurs hybrides
1) Refroidissement des machines frigorifiques
2) Free-cooling



H) Chaudières à gaz à condensation
1) Appoint en cas de conditions extrêmes
2) Secours

Energie à haute température

G) Chaudière à granulés
1) Production de chaleur à haute température neutre en CO2



K) Galvanoplastie (Bains à 60 °C)

F) Production d'air comprimé
1) Récupération de chaleur
2) Refroidissement en cas d'excès

F) High efficieny variable speed 3 stage turbo air compressor, rejected heat used for heating needs

C) Machines frigorifiques centrifuges à vitesse variable et à paliers magnétiques
1) Refroidissement ventilation, poutres froide, Refroidissements des processus
2) Chauffage en mode pompe à chaleur

Refroidissement et déshumidification

Chauffage en mode pompe à chaleur

Récupération de chaleur

D) Captage nappe phréatique
1) source de chaleur pour les machines frigorifiques
2) refroidissement des process, machines, ...

Refroidissement de base

E) Centrales de traitement d'air des ateliers
1) Récupération de chaleur rotative à enthalpie

Récupération de chaleur

I) High temperature chilled water → passive chilled beams

A) Cooling of the machining process, temperature level at 18-24°C, used for air reheating possible

I) Poutres froides (lorsque les charges dépassent 50 W/m2)

L) High performance building envelope

L) Enveloppe du bâtiment performante (Label Minergie)

J) Installation solaire photovoltaïque

J) Solar Photovoltaic

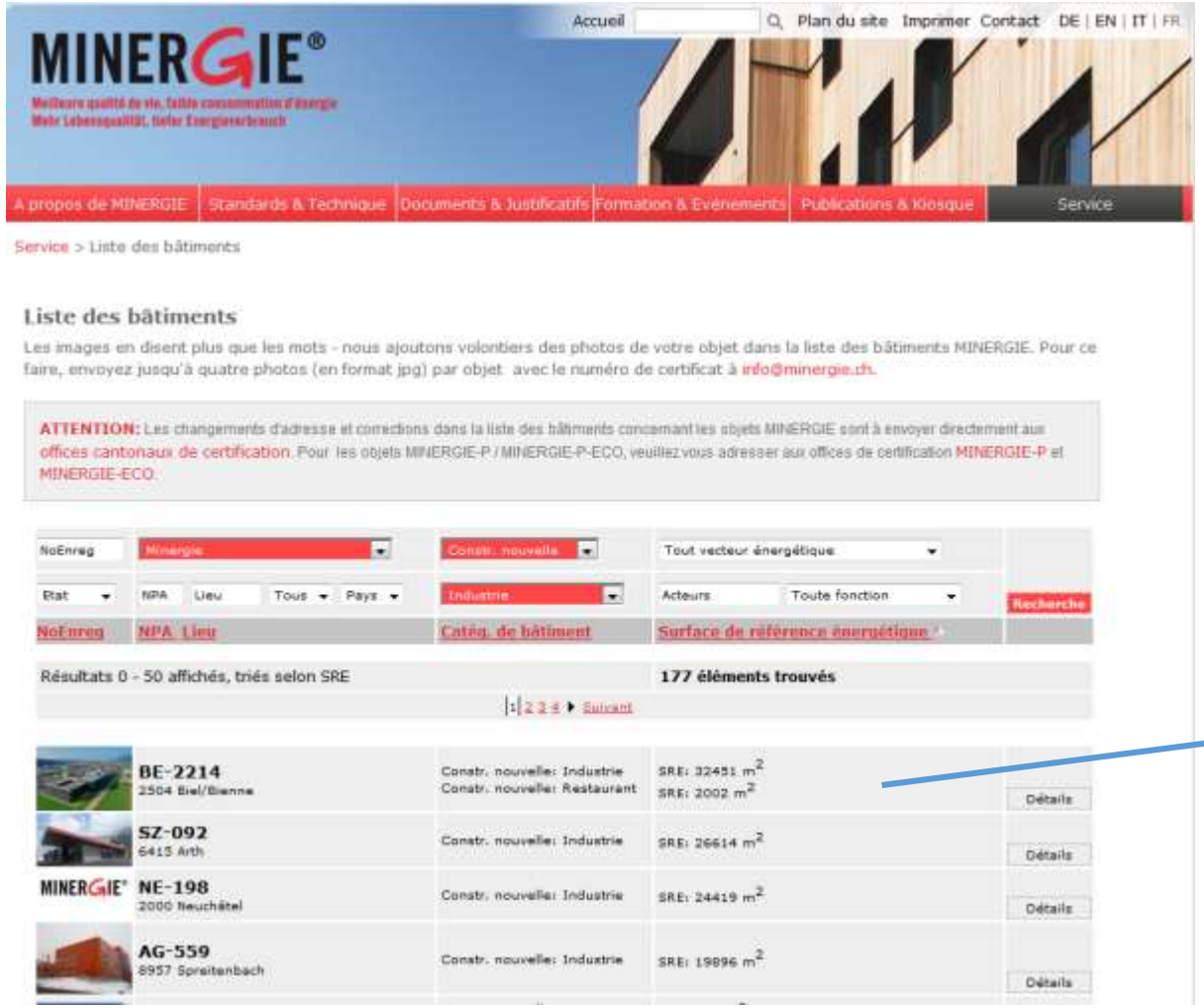
D) Underground water for part supply

E) High efficiency air handling units with heat recovery (Enthalpy 85%, water for process cooling supplying heat fo rthe

Effin'Art
The Art of Energy Efficiency

Energy efficiency label

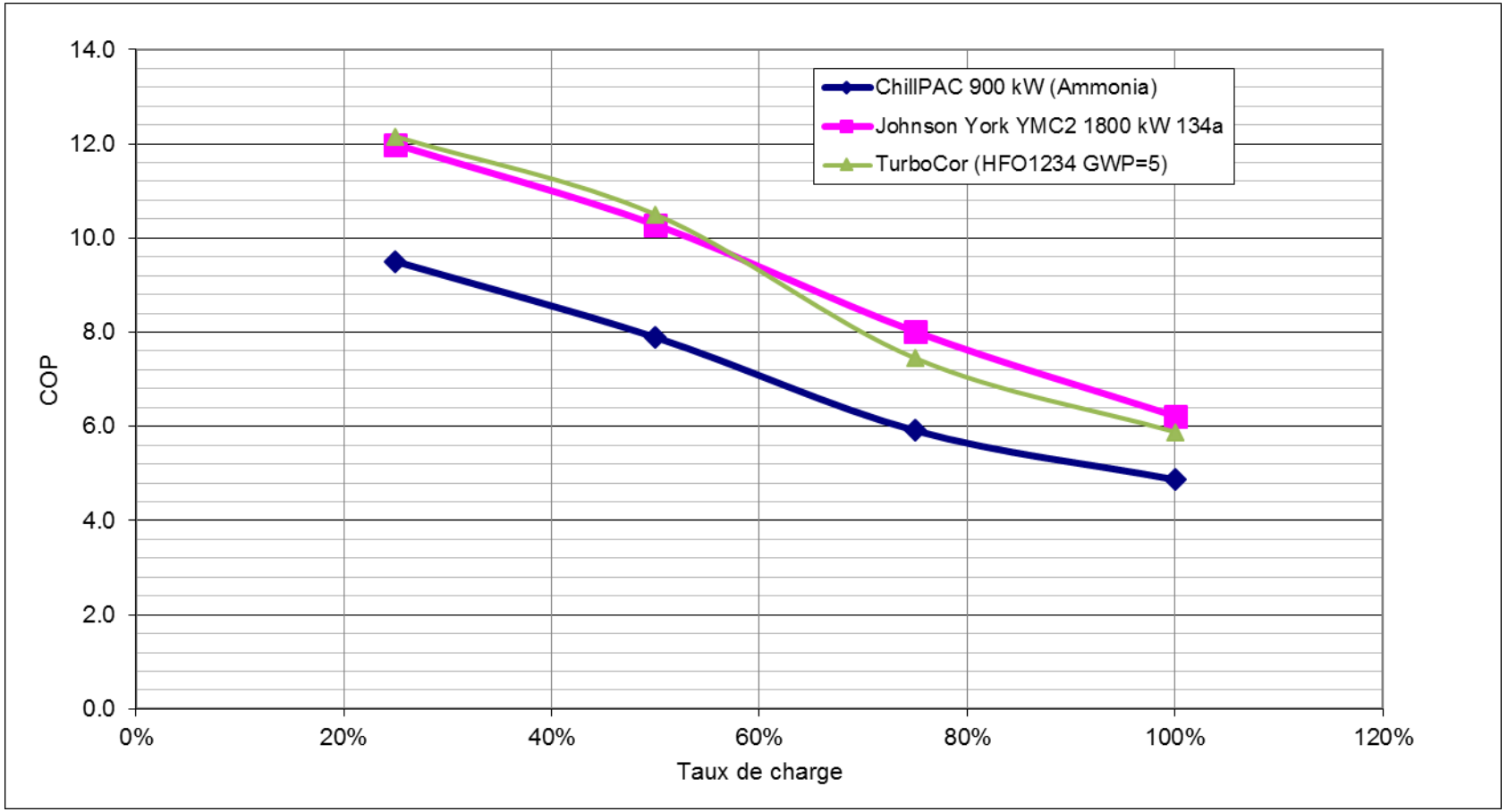
- Largest Minergie certified industrial area in 2012



Effin'Art
The Art of Energy Efficiency

Chillers technology change and controls

- Comparison between the COP as per (AHRI 550)
  - Johnson York ChillPAC pistons, variable speed (Ammoniac)
  - Johnson York YMC2 Turbo (134a
  - TurboCor (HFO 1234 GWP =5)
- Variable flow chilled water and condensing water
- Gliding temperature of chilled water



Rolex Learning Center EPFL
Design competition winners:
Architectes: SANAA, Tokyo, Pritzker Price 2010

- Futurist dream
- Only to become real !!!

Ventilé **naturellement**
TRACÉS nº 12 · 1er juillet 2009
Pierre Jaboyedoff

Bauwelt 13|2010

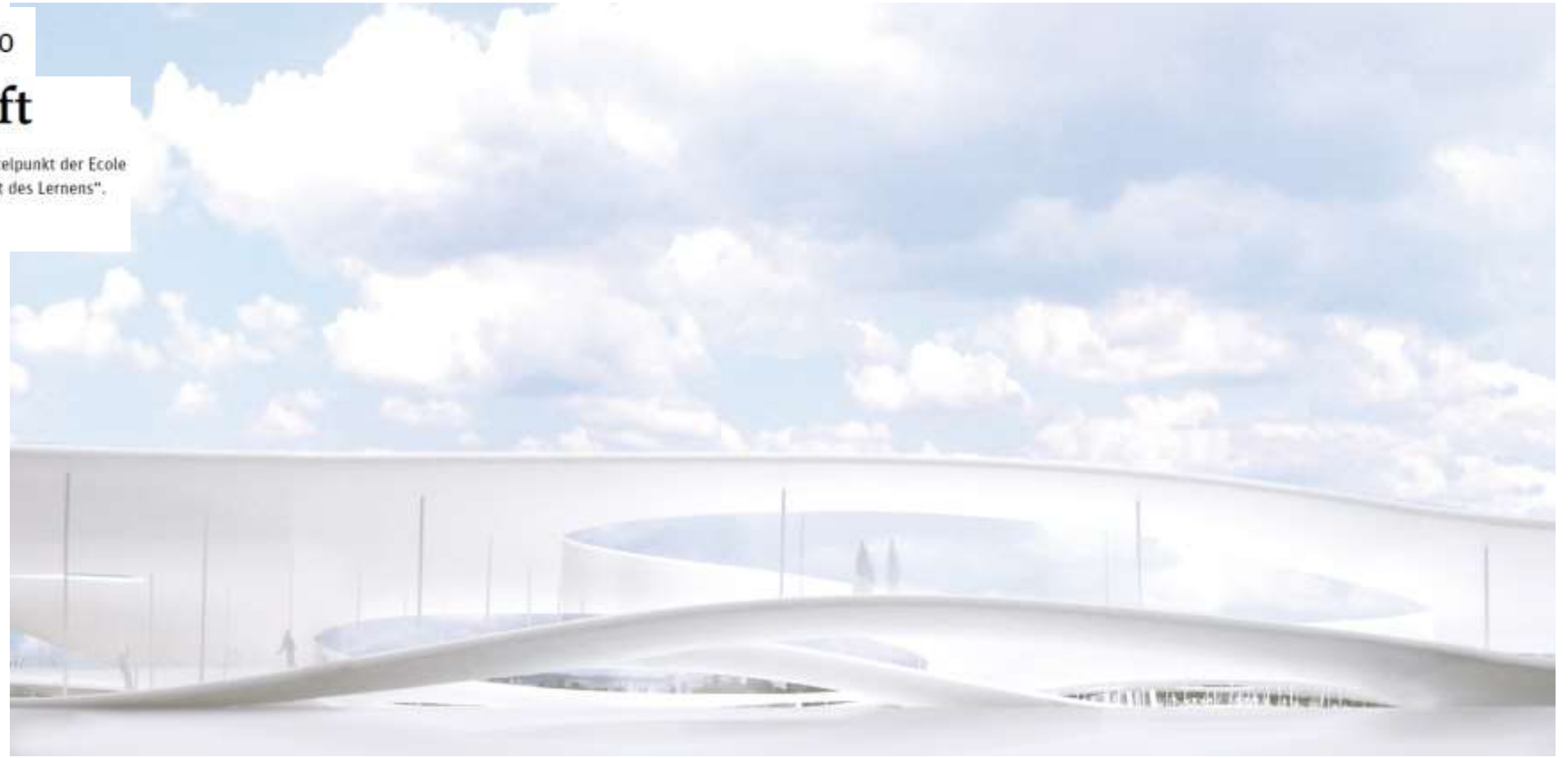
Bauwelt 13|2010

Campus mit Teppichlandschaft

Das Rolex Learning Center von **Kazuyo Sejima und Ryue Nishizawa, SANAA,** bildet den neuen Mittelpunkt der Ecole Polytechnique Fédérale de Lausanne. Der Präsident der Hochschule schwärmt von der „neuen Art des Lernens".

Kritik **Sebastian Redecke** Fotos **Christian Richters**

Energiekonzept
Pierre Jaboyedoff, Sorane SA, Ecublens



Project in charge P. Jaboyedoff with D Chuard when employed by Sorane

Effin'Art
The Art of Energy Efficiency

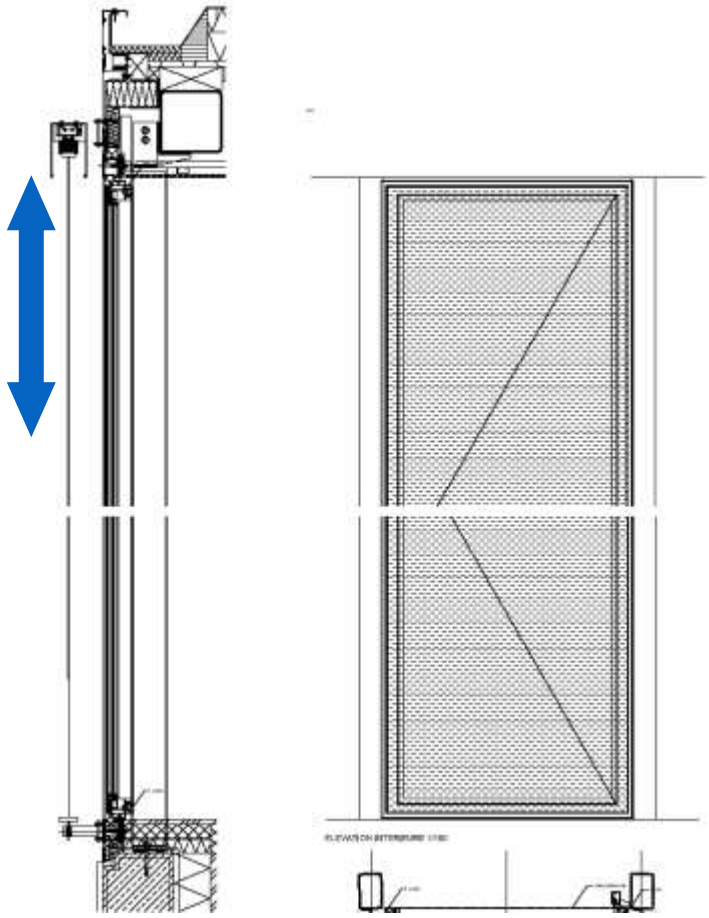
Rolex Learning Center EPFL
High performance glazings

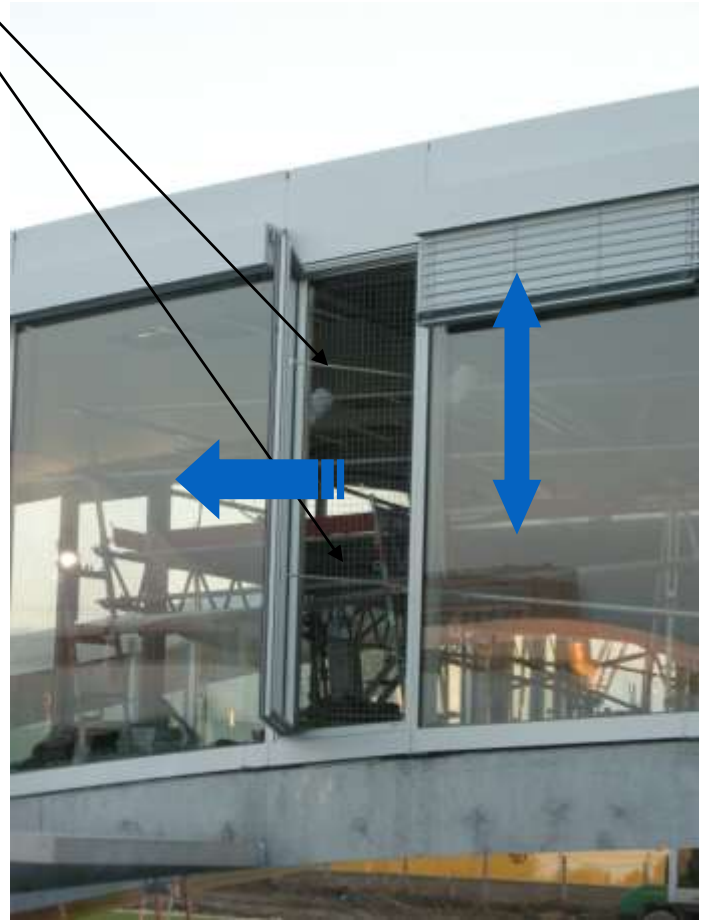
- Curved double high performance glazings U: 1.1 W/m^2-K

Effin'Art
The Art of Energy Efficiency

Natural ventilation opening control and retractable external lamella blinds

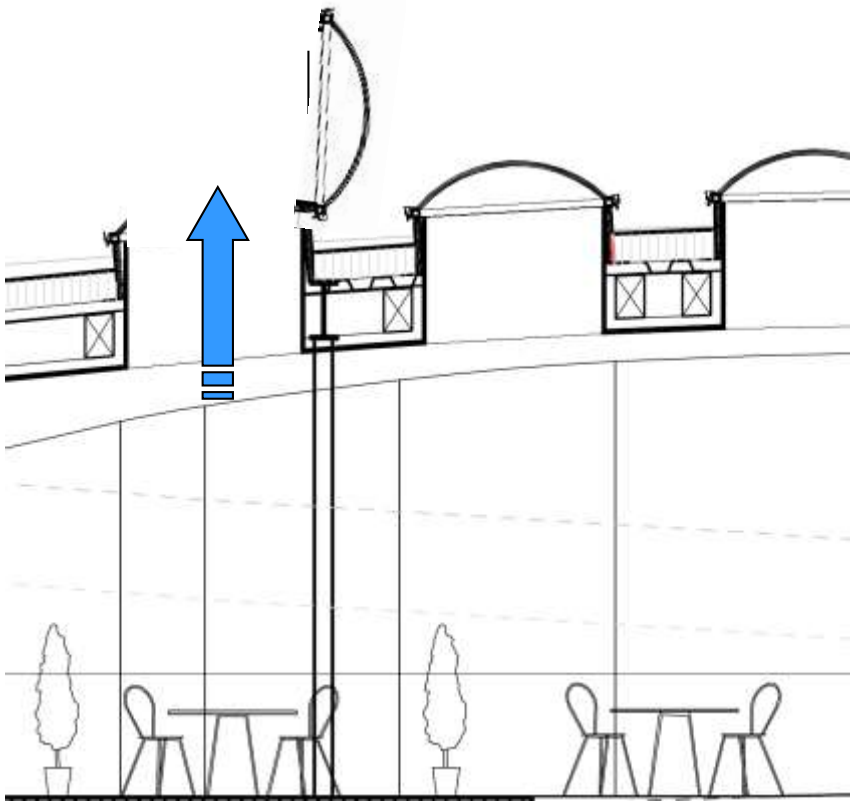
- Brises-soleil orientables sur les patios et les façades extérieures
- Ouvrants motorisés sur les patios (2 moteurs pour assurer une étanchéité parfaite)





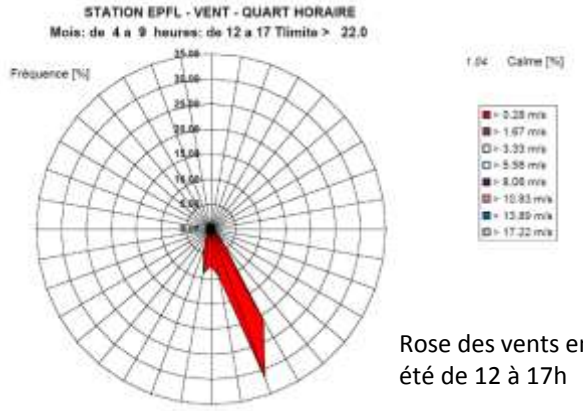
Effin'Art
The Art of Energy Efficiency

Roof vents for natural ventilation and fire smoke extraction

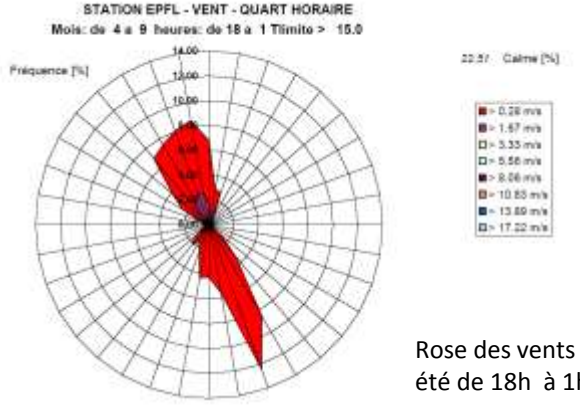


Effin'Art
The Art of Energy Efficiency

Summer wind rose and overheating areas with CFD simulation

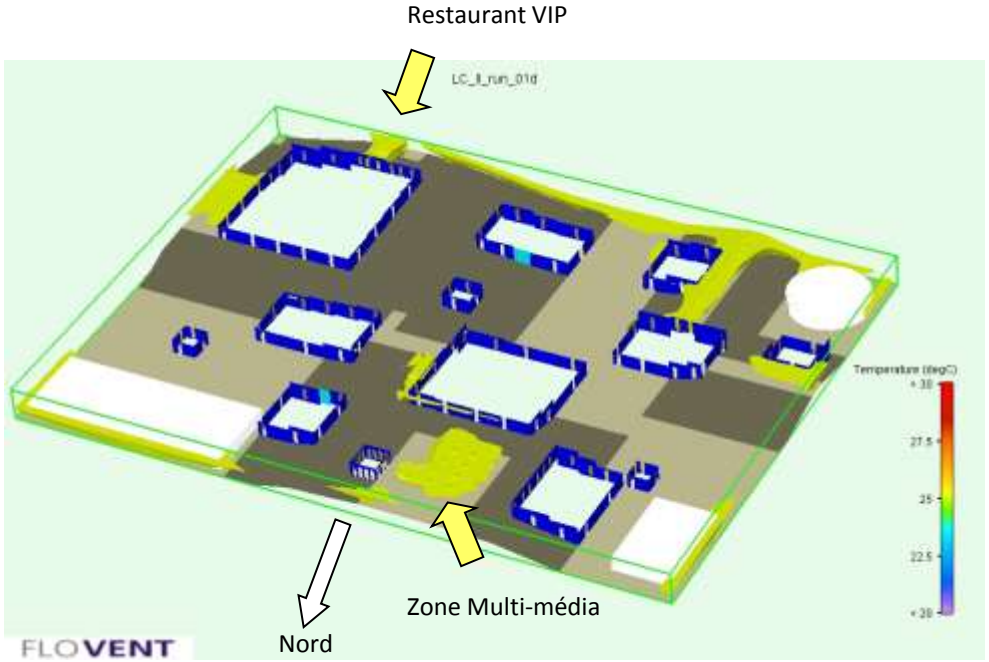


Rose des vents en été de 12 à 17h



Rose des vents en été de 18h à 1h

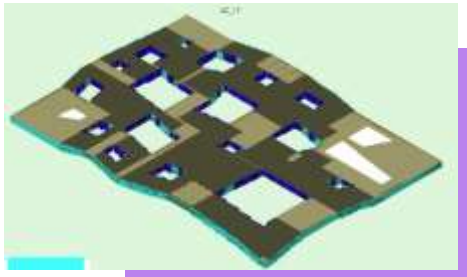
- Rose des vents
- Simulation des écoulements d'air en condition estivale
- Zones de surchauffe



Effin'Art
The Art of Energy Efficiency

Natural ventilation modelling
Summer overheating: original architect design

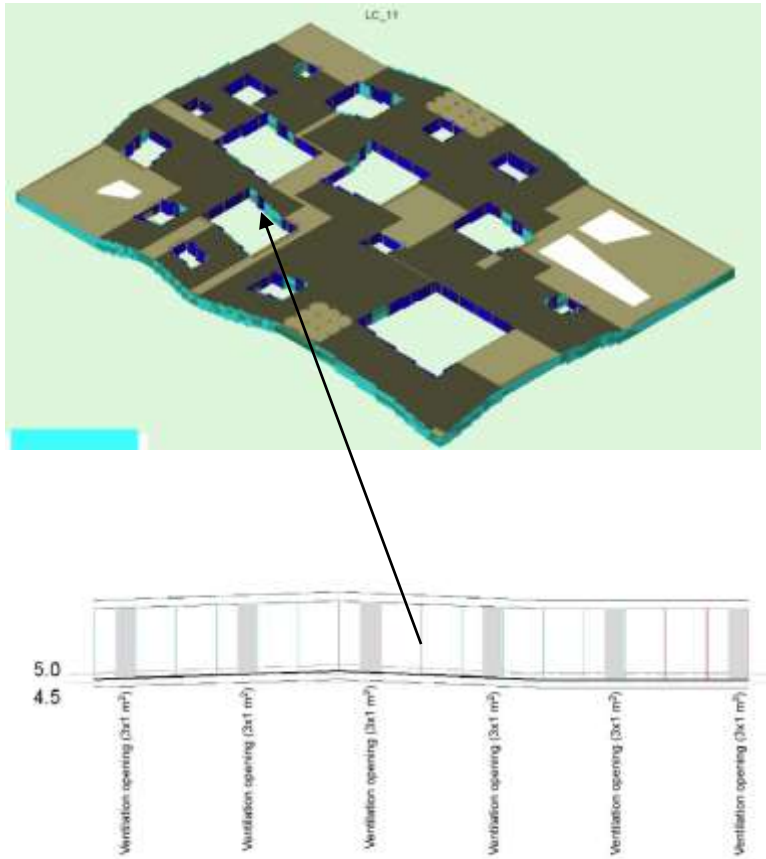
- CFD model 8.5 millions mesh



Effin'Art
The Art of Energy Efficiency

Iterations with architect

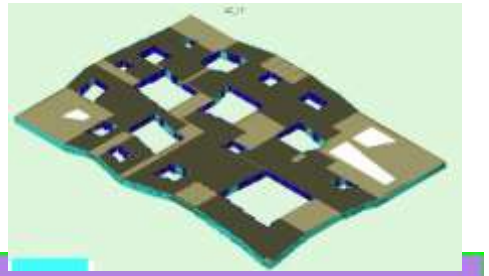
- CFD Simulation
- Results
- Architectural changes
  - More openings
  - Larger openings
  - …
- CFD Simulation ….

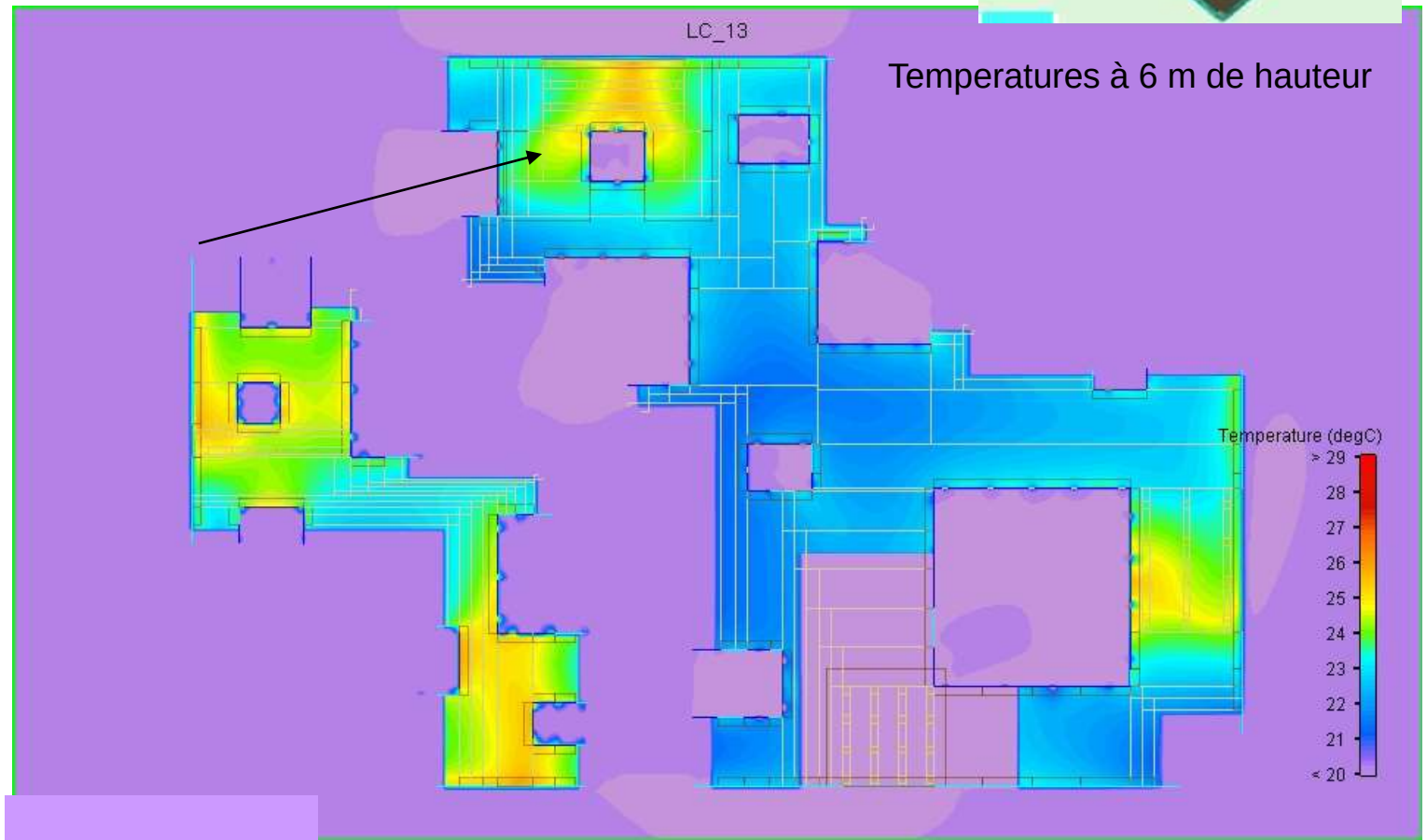


Effin'Art
The Art of Energy Efficiency

Solution after many iterations (about 600 hours CFD computing time)

- Bearable temperature level
- Obtained by a combination of openings and control
  - Patios
  - Doors
  - Roof opening
  - Localised radiant cooling
- CFD model used also for fire simulations





Effin'Art
The Art of Energy Efficiency

Dynamic simulation with intermodel comparison CFD-TRNSYS

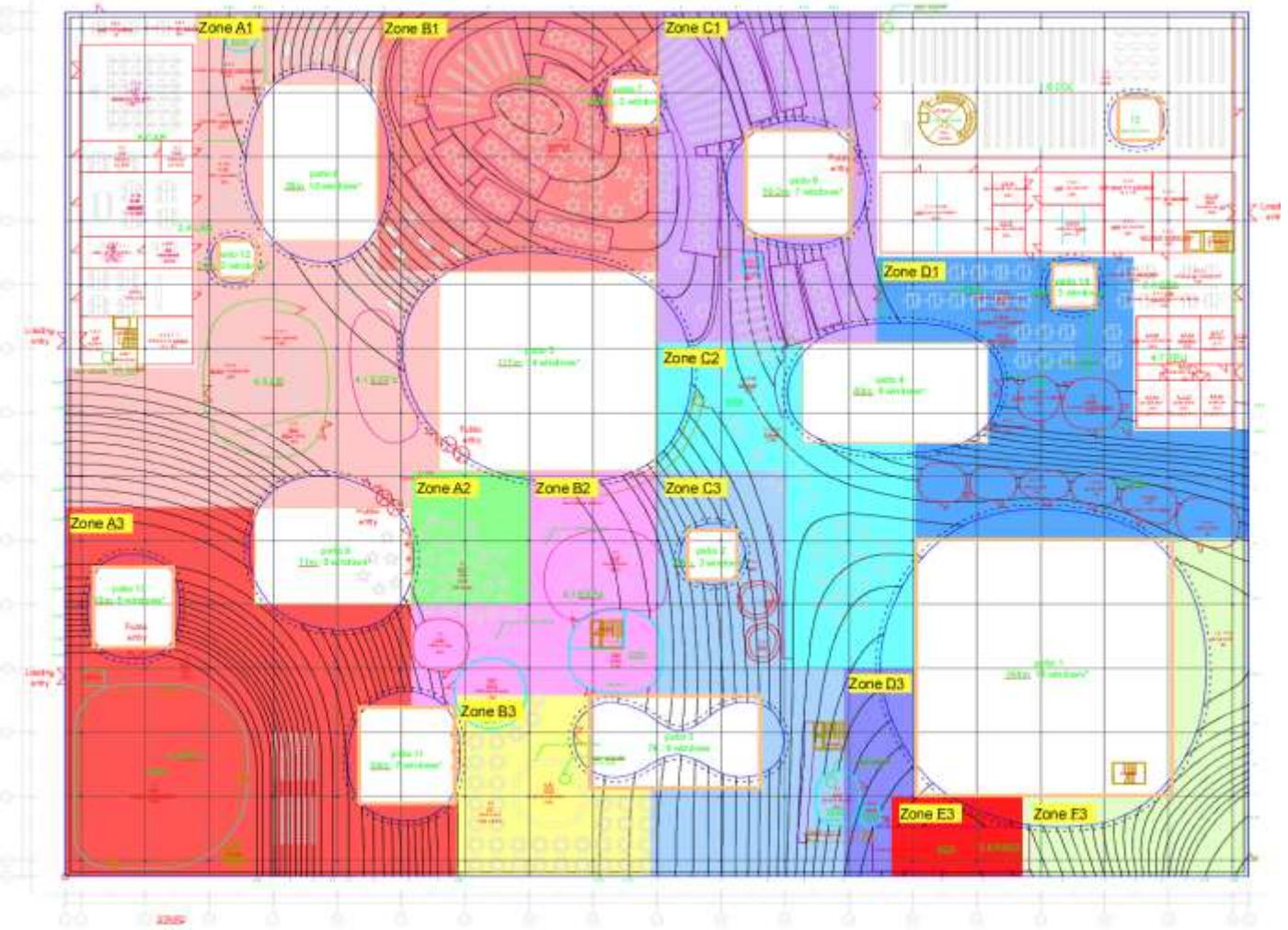
Flovent

CFD

TRNSYS

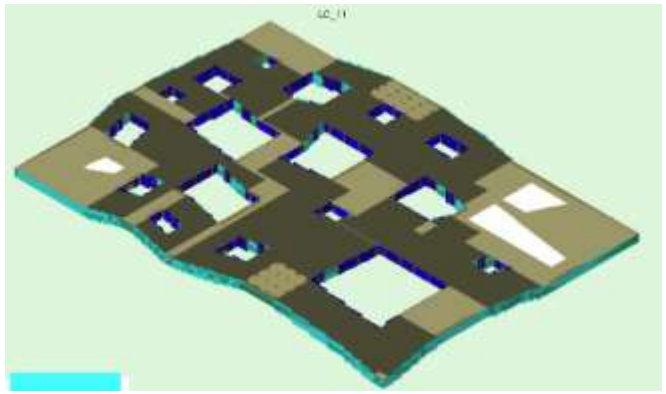
Simul thermo-aéraulique

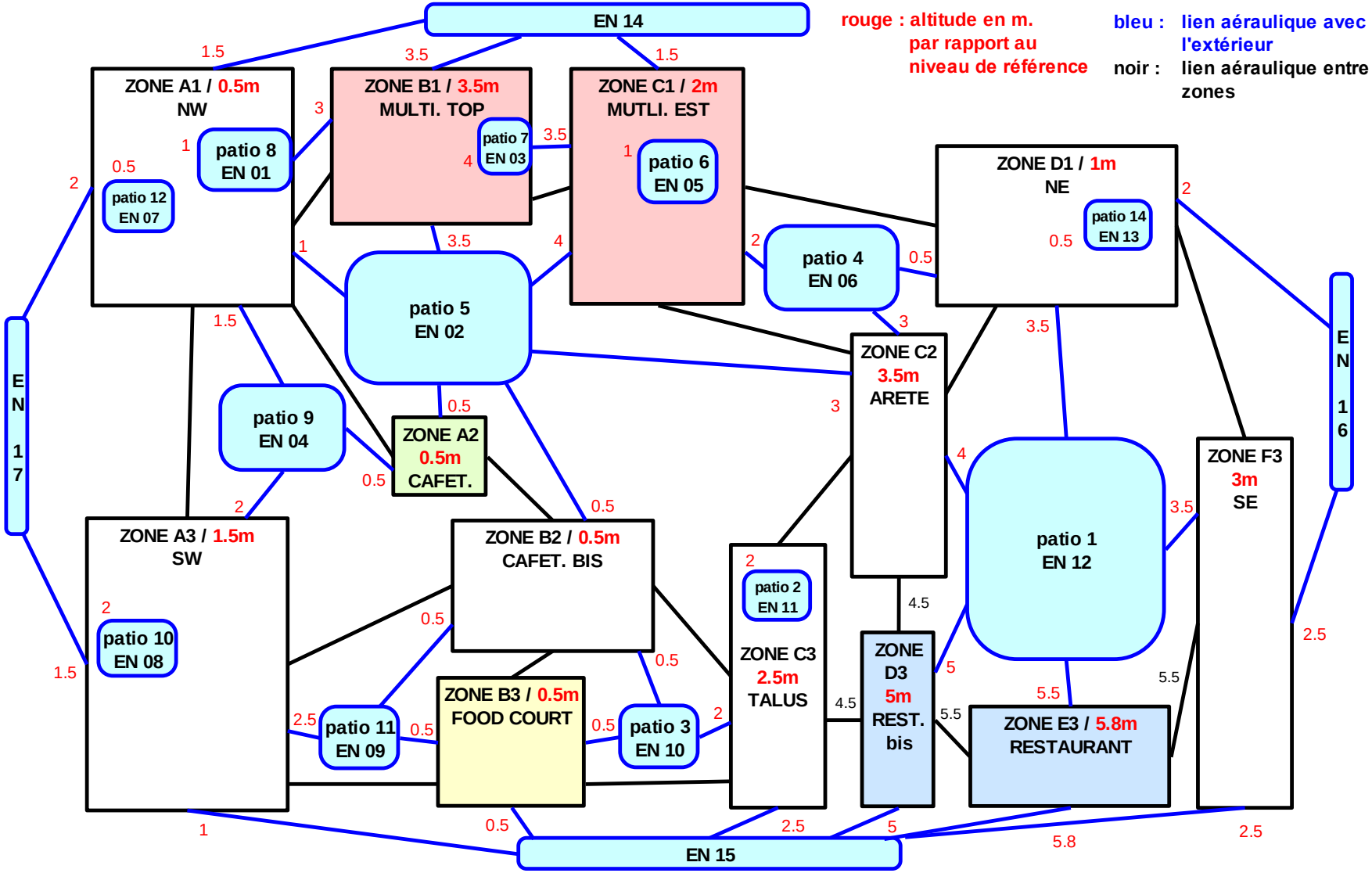
- Simulated zones with TRNSYS-TRNFLOW (each zone has a different color)



Effin'Art
The Art of Energy Efficiency

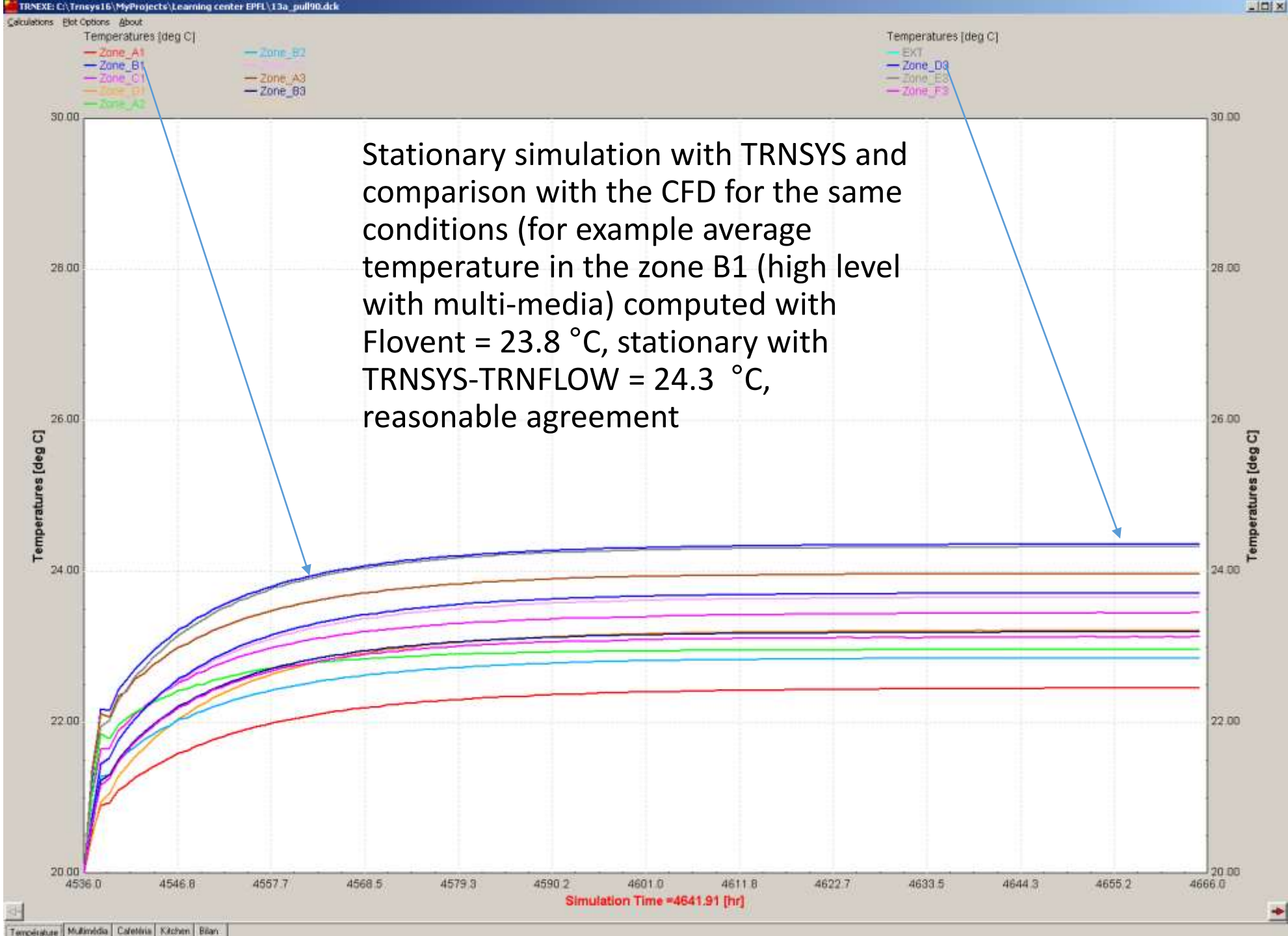
TRNFLOW model coupled to the thermal simulation (in red in zones: altitude of each zone, in blue : openings to the ambiant, in black : link betwee two zones)





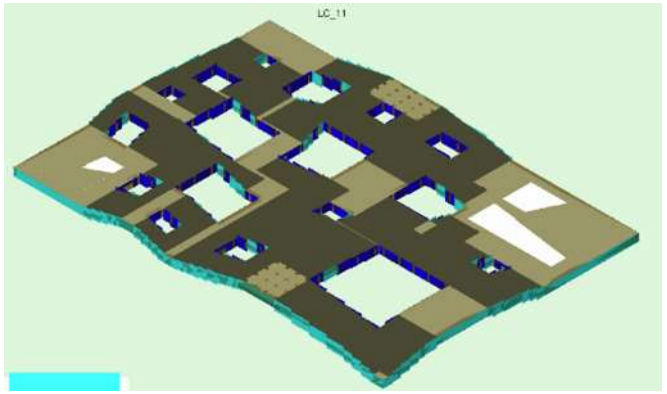
Effin'Art
The Art of Energy Efficiency

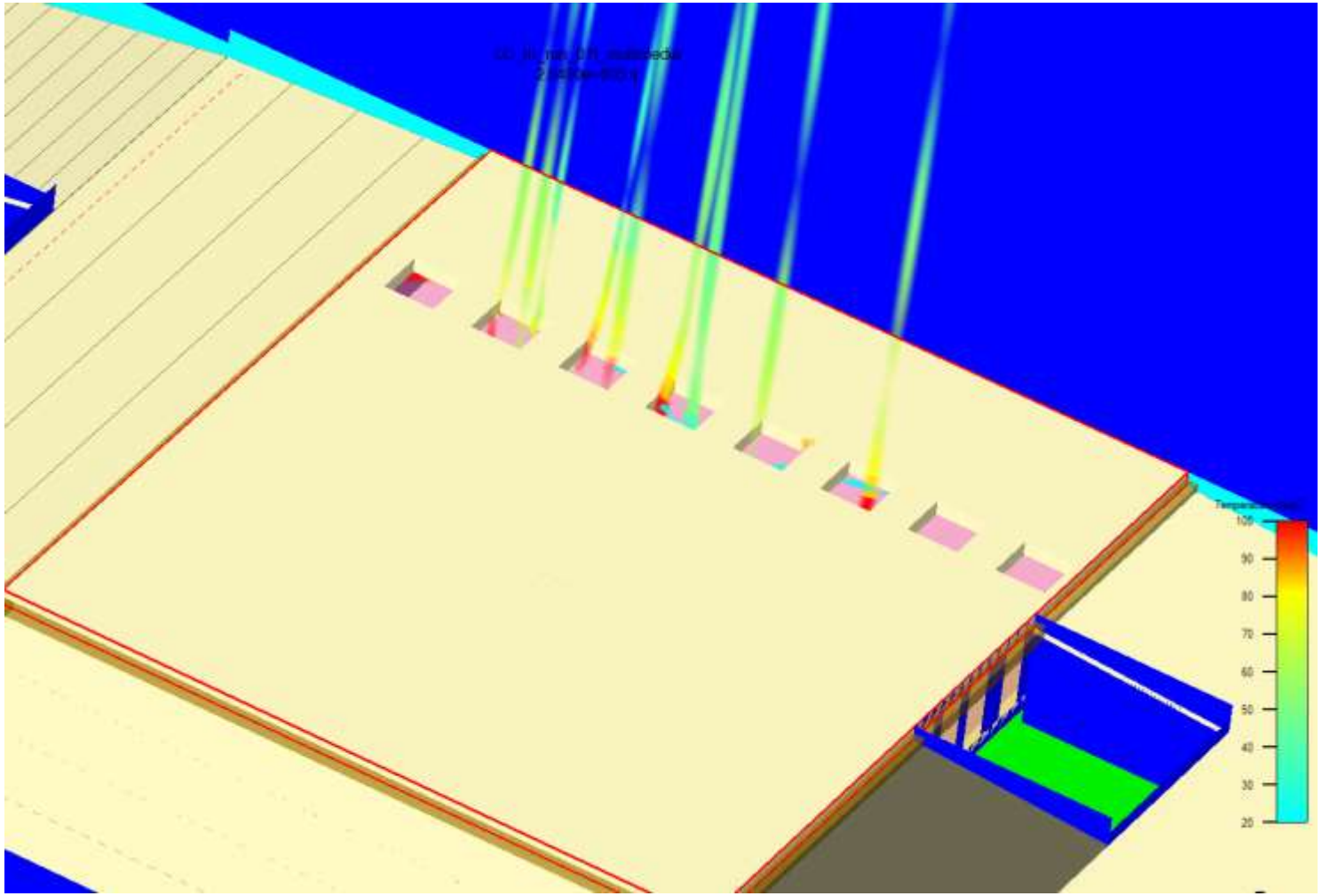
Comparison of Simulation (TRNSYS) versus ←→ CFD Flovent



Effin'Art
The Art of Energy Efficiency

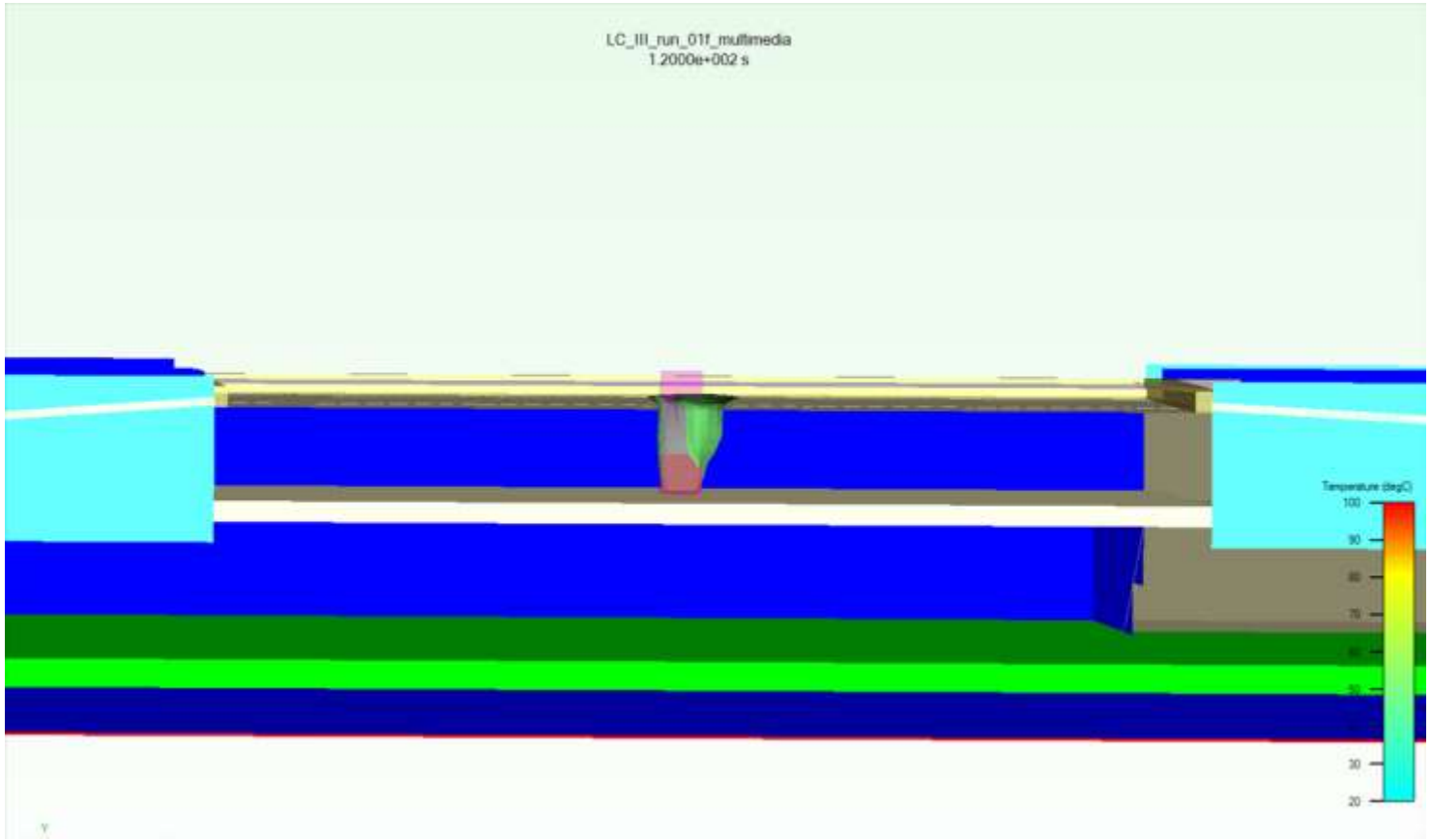
Natural smoke extraction in case of fire in the multi-media zone, could avoid any fire curtain in the Rolex Learning Center





Effin'Art
The Art of Energy Efficiency

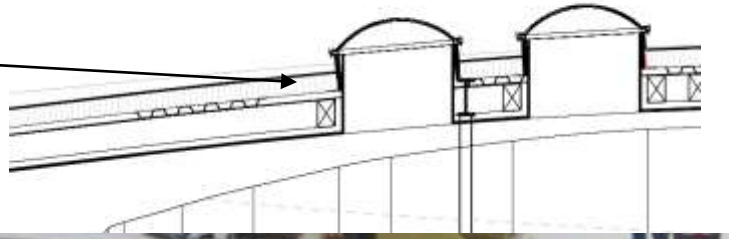
Désenfumage de la zone Bibliothèque



Effin'Art
The Art of Energy Efficiency

Insulation of the roof

- External insulation
  - 20 cm
  - Rockwool



Effin'Art
The Art of Energy Efficiency

Shell insulation

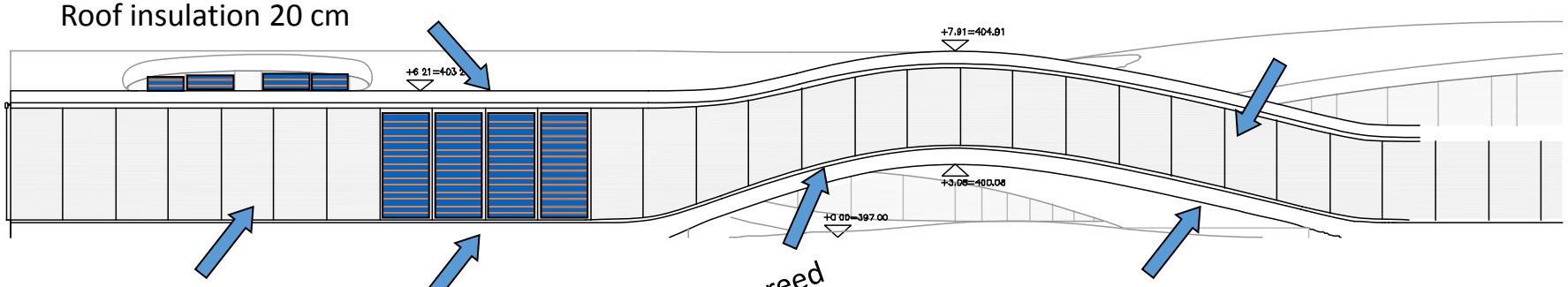
- Concrete shell
  - Insulation from inside (architect wanted to have visible concrete under the building)
- Thickness > 15 cm <= 40 cm

Effin'Art
The Art of Energy Efficiency

Building envelope

Tight facade

Roof insulation 20 cm



High performance glazings

Movable external lamella blinds

Heavy screed

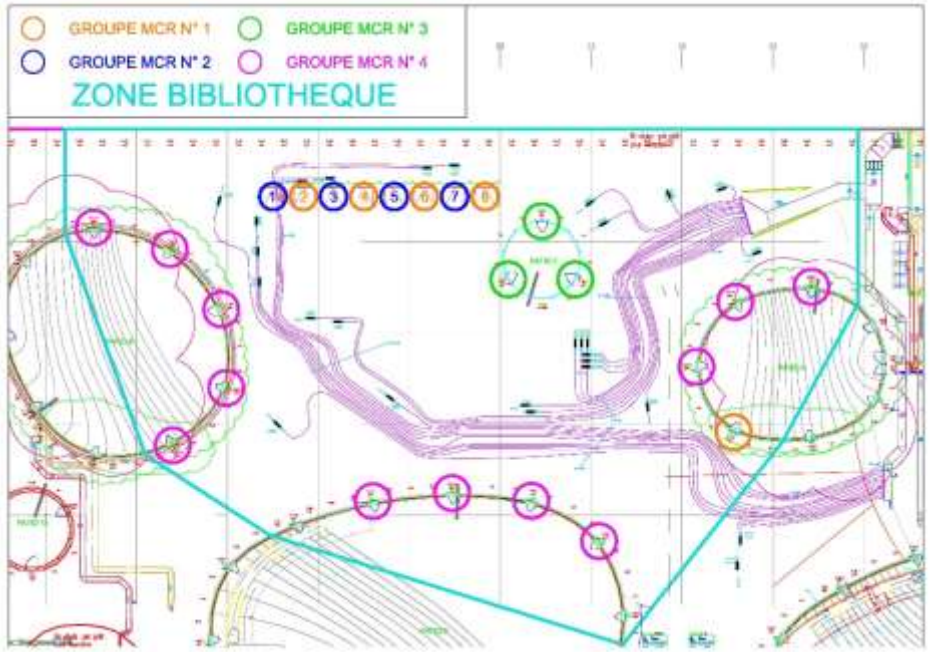
Shell insulation 15-40 cm

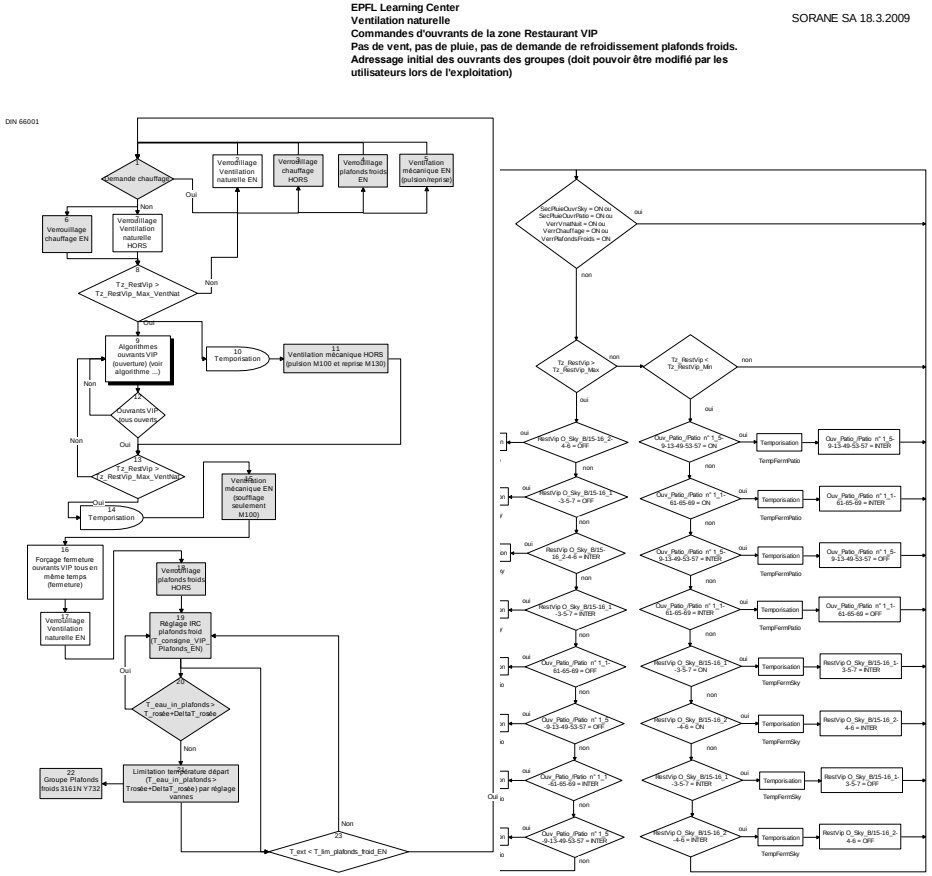
Effin'Art
The Art of Energy Efficiency

MCR GTB
Contrôle climatique estival

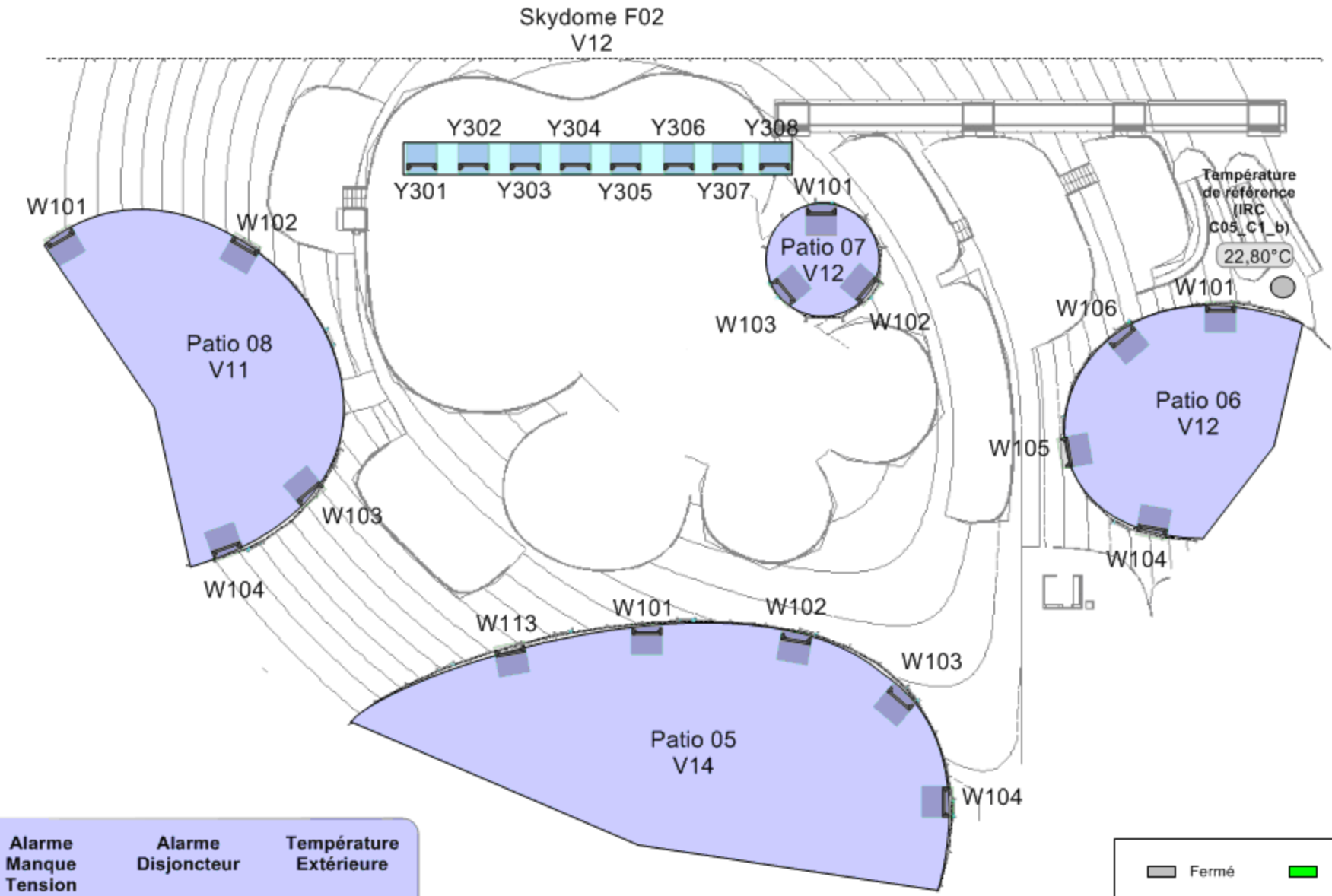
Algorithmes spécifiquement développés pour ce bâtiment

- Chaque ouvrant est paramétré de manière indépendante





ZONE 2 - BIBLIOTHEQUE



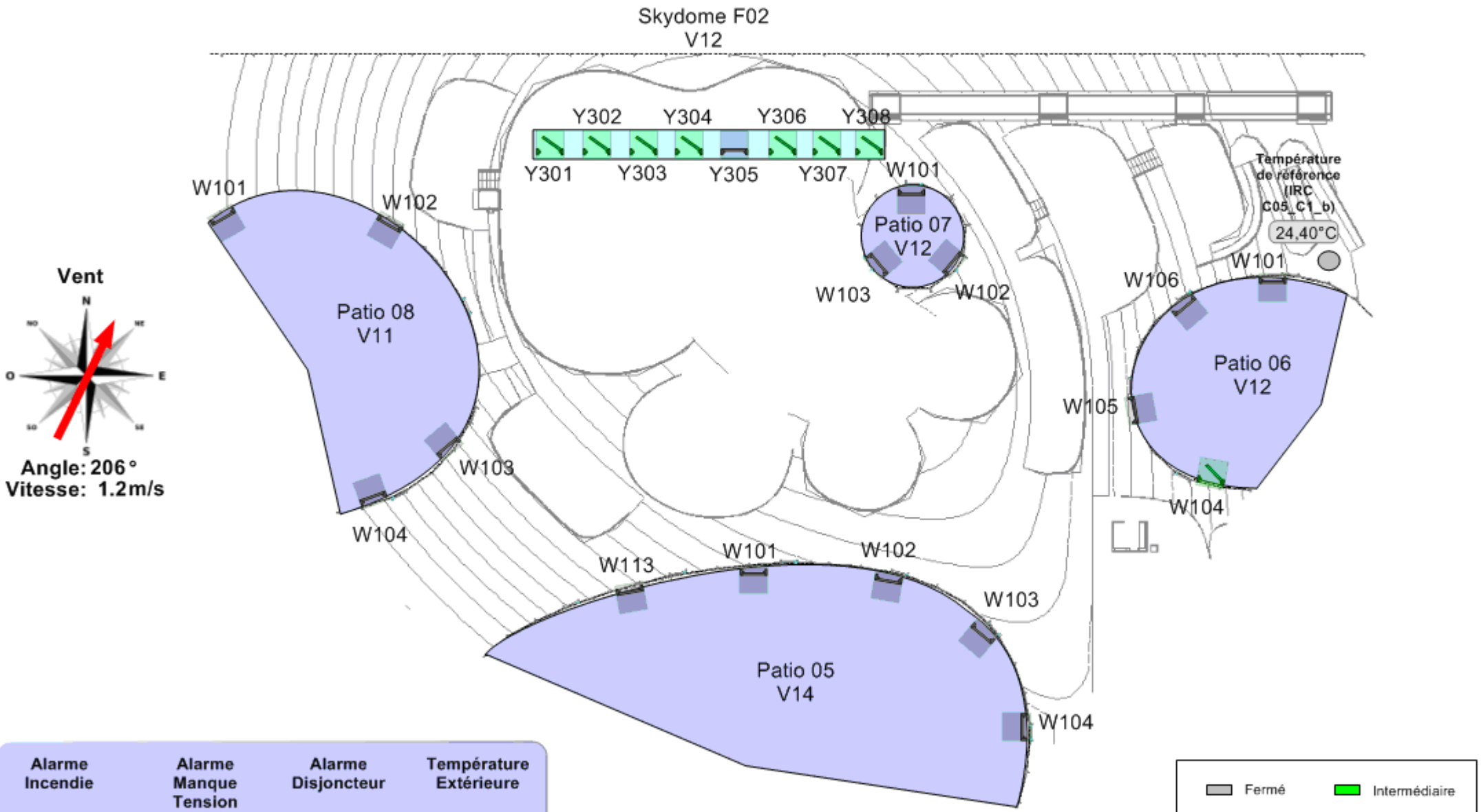
Vent

Angle: 19°
Vitesse: 1.2m/s

Alarme Incendie	Alarme Manque Tension	Alarme Disjoncteur	Température Extérieure
V11 V12 V14	V11 V12 V14	V11 V12 V14	14,34°C

Fermé
Intermédiaire
Sécurité
Ouvert

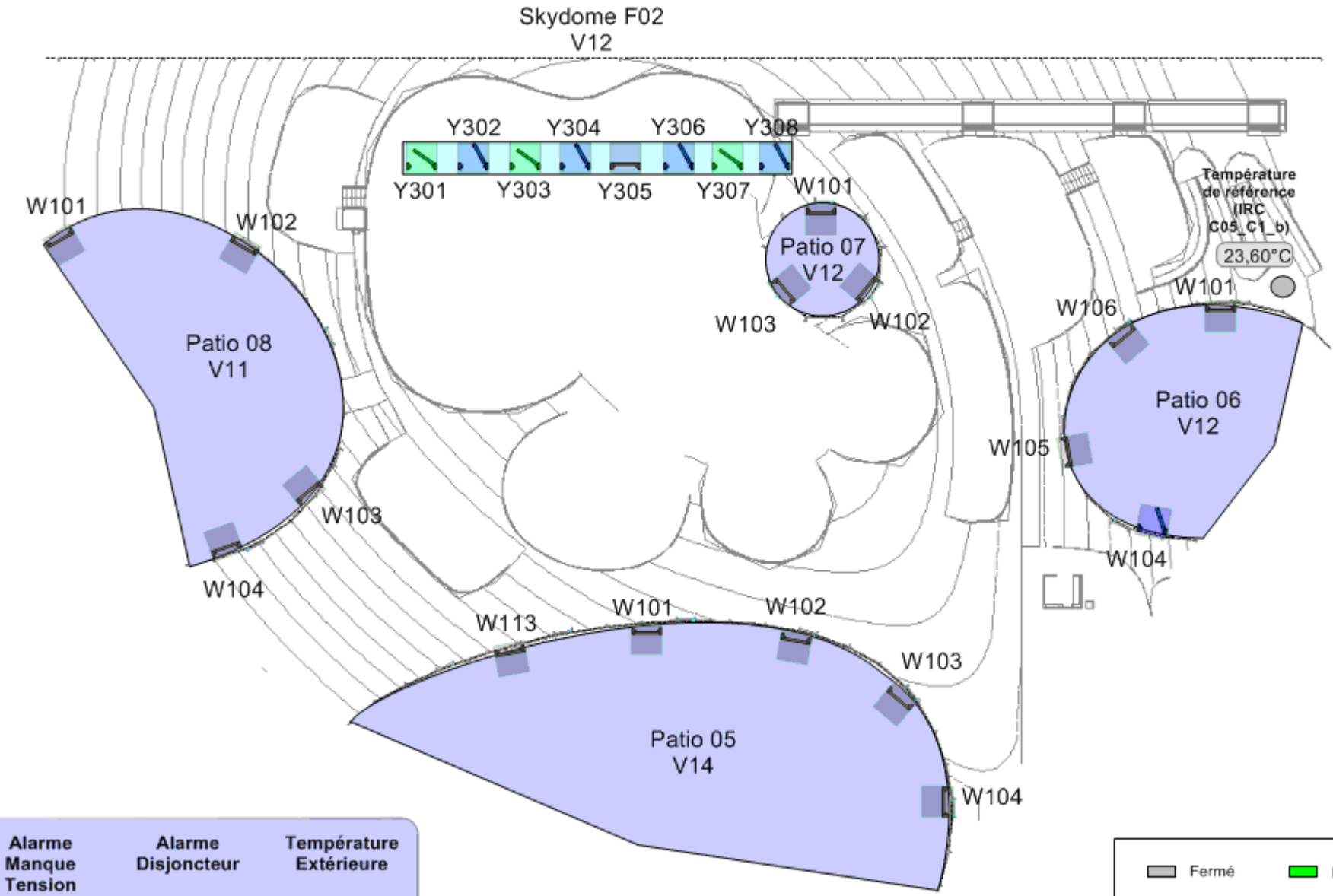
ZONE 2 - BIBLIOTHEQUE



Alarme Incendie	Alarme Manque Tension	Alarme Disjoncteur	Température Extérieure
V11 V12 V14	V11 V12 V14	V11 V12 V14	20,29°C

Fermé
Intermédiaire
Sécurité
Ouvert

ZONE 2 - BIBLIOTHEQUE



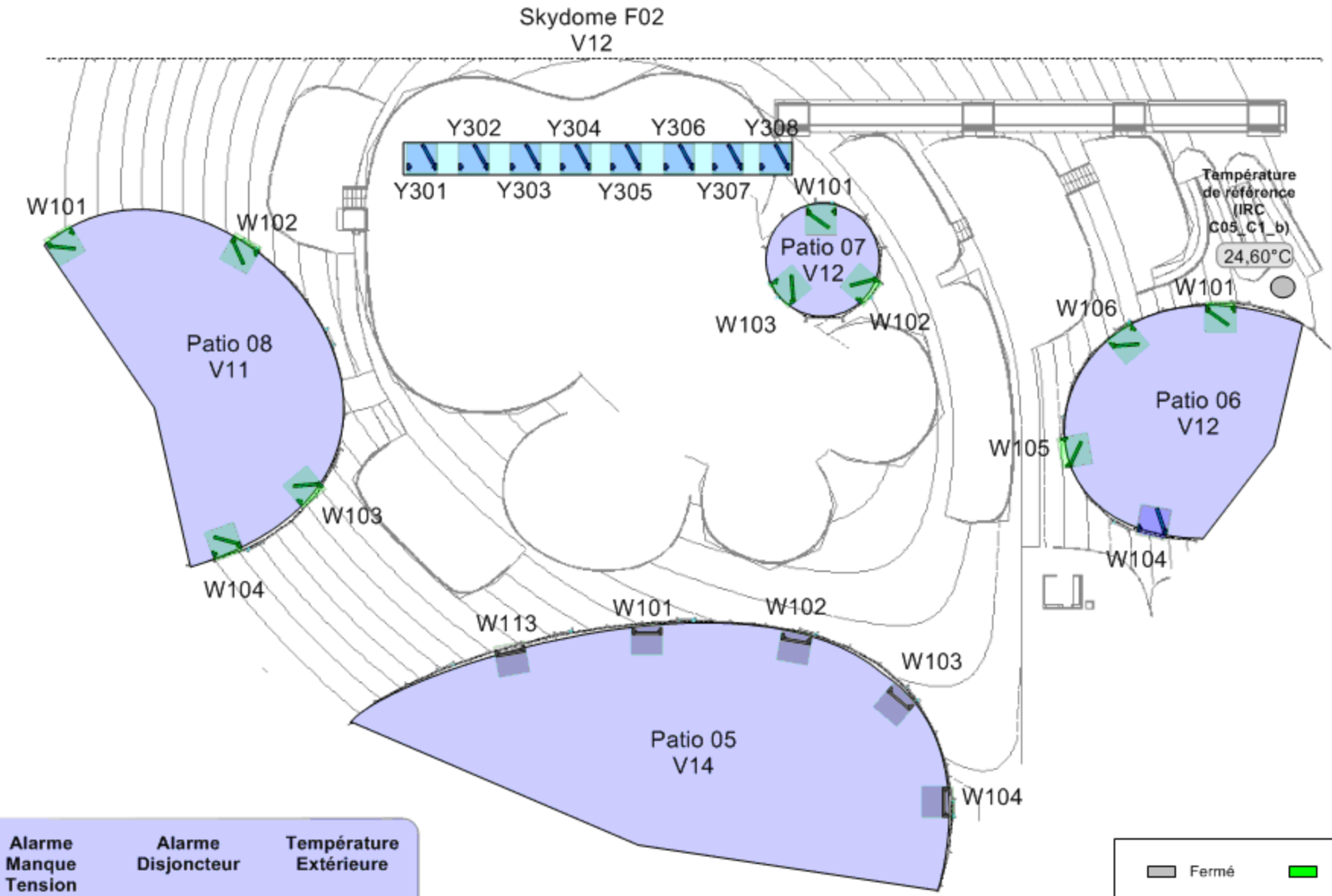
Vent

Angle: 116°
Vitesse: 1.9m/s

Alarme Incendie	Alarme Manque Tension	Alarme Disjoncteur	Température Extérieure
V11 V12 V14	V11 V12 V14	V11 V12 V14	21,44°C

Fermé
Intermédiaire
Sécurité
Ouvert

ZONE 2 - BIBLIOTHEQUE



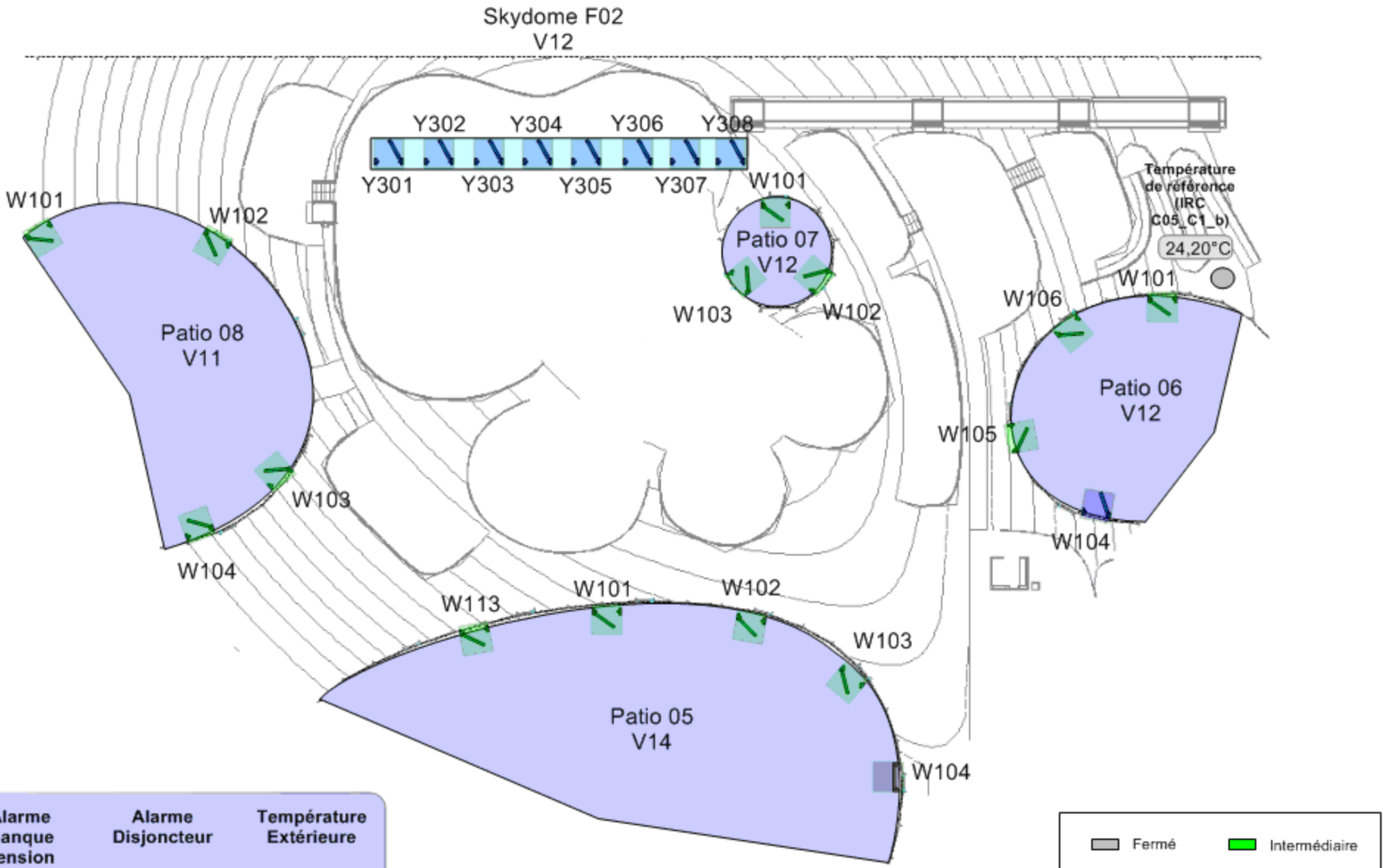
Vent

Angle: 172°
Vitesse: 1m/s

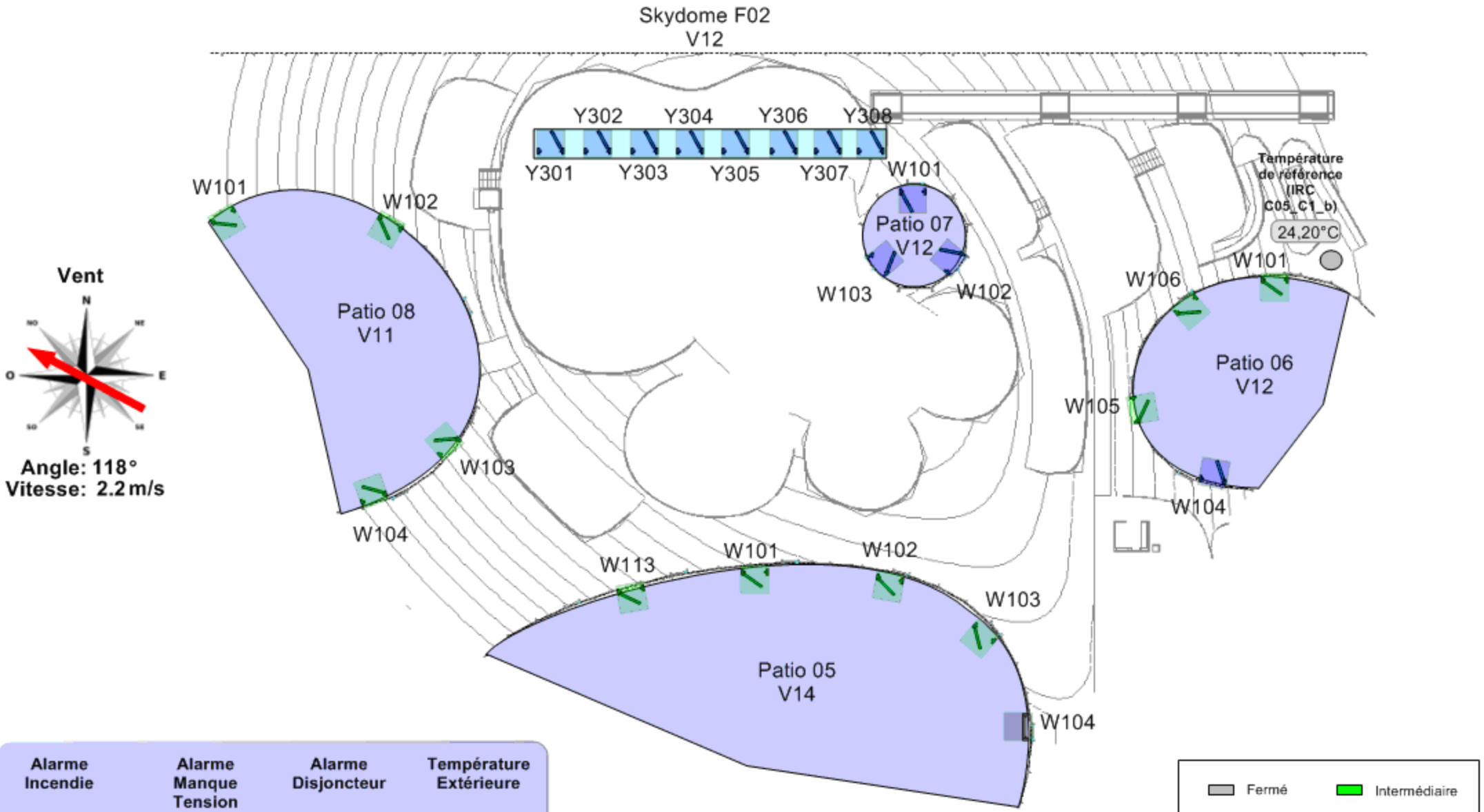
Alarme Incendie	Alarme Manque Tension	Alarme Disjoncteur	Température Extérieure
V11 V12 V14	V11 V12 V14	V11 V12 V14	19,29°C

Fermé
Intermédiaire
Sécurité
Ouvert

ZONE 2 - BIBLIOTHEQUE



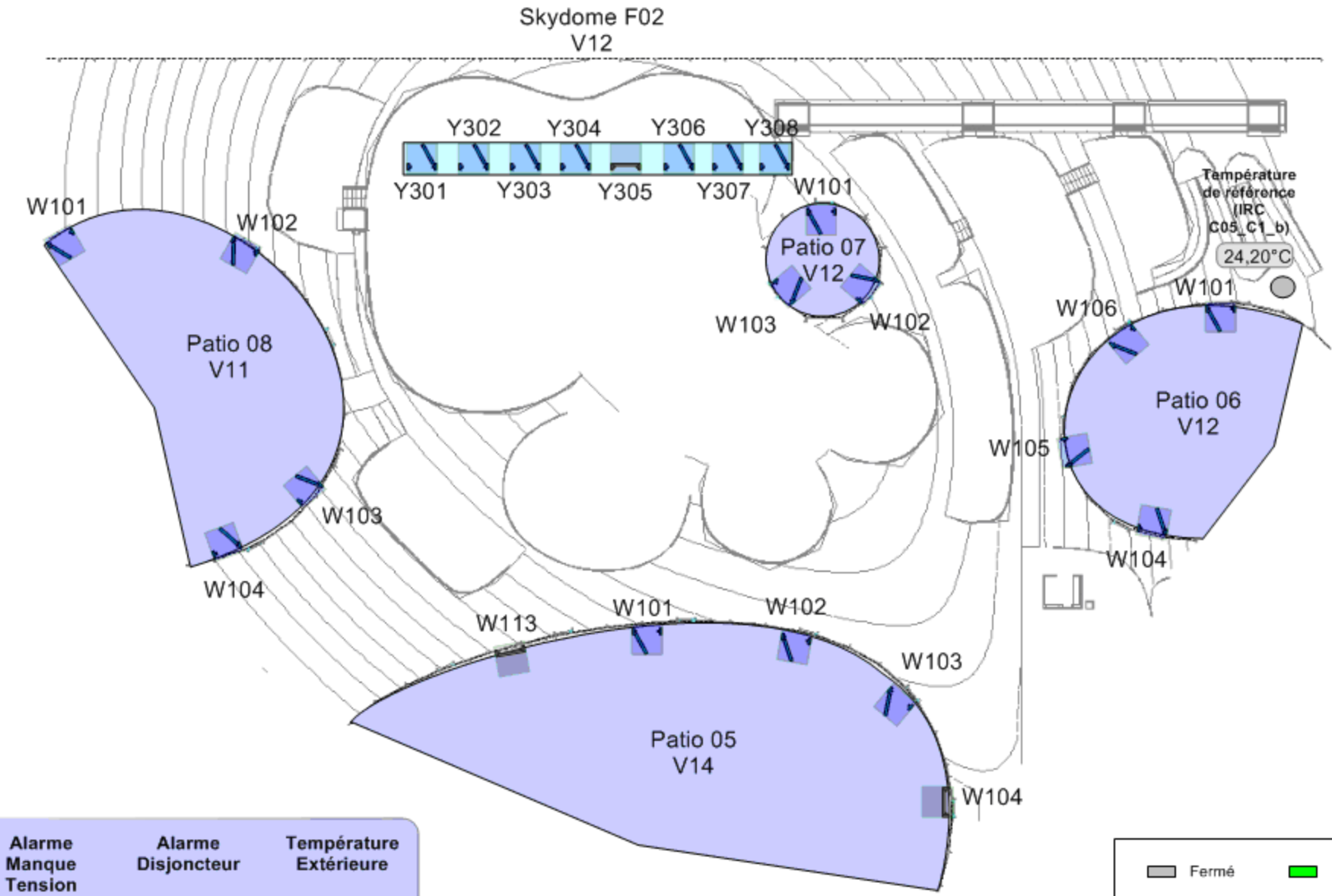
ZONE 2 - BIBLIOTHEQUE



Alarme Incendie	Alarme Manque Tension	Alarme Disjoncteur	Température Extérieure
V11 V12 V14	V11 V12 V14	V11 V12 V14	22,15°C

Fermé
Intermédiaire
Sécurité
Ouvert

ZONE 2 - BIBLIOTHEQUE



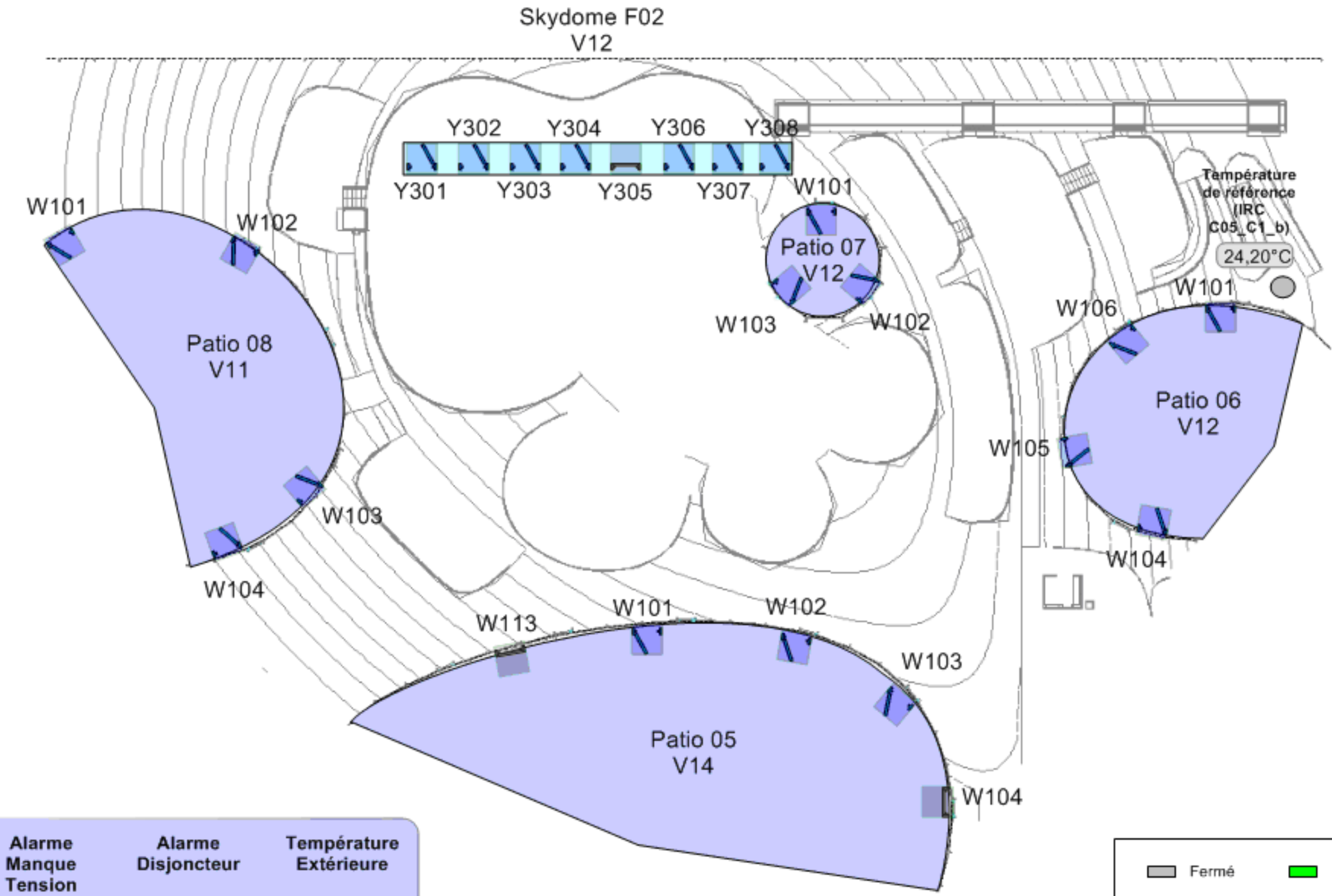
Vent

Angle: 145°
Vitesse: 0.5 m/s

Alarme Incendie	Alarme Manque Tension	Alarme Disjoncteur	Température Extérieure
V11 V12 V14	V11 V12 V14	V11 V12 V14	25,53°C

Fermé
Intermédiaire
Sécurité
Ouvert

ZONE 2 - BIBLIOTHEQUE



Vent

Angle: 136°
Vitesse: 1.1m/s

Alarme Incendie	Alarme Manque Tension	Alarme Disjoncteur	Température Extérieure
V11 V12 V14	V11 V12 V14	V11 V12 V14	26,13°C

Fermé
Intermédiaire
Sécurité
Ouvert

Effin'Art
The Art of Energy Efficiency

Rolex Learning Center as built

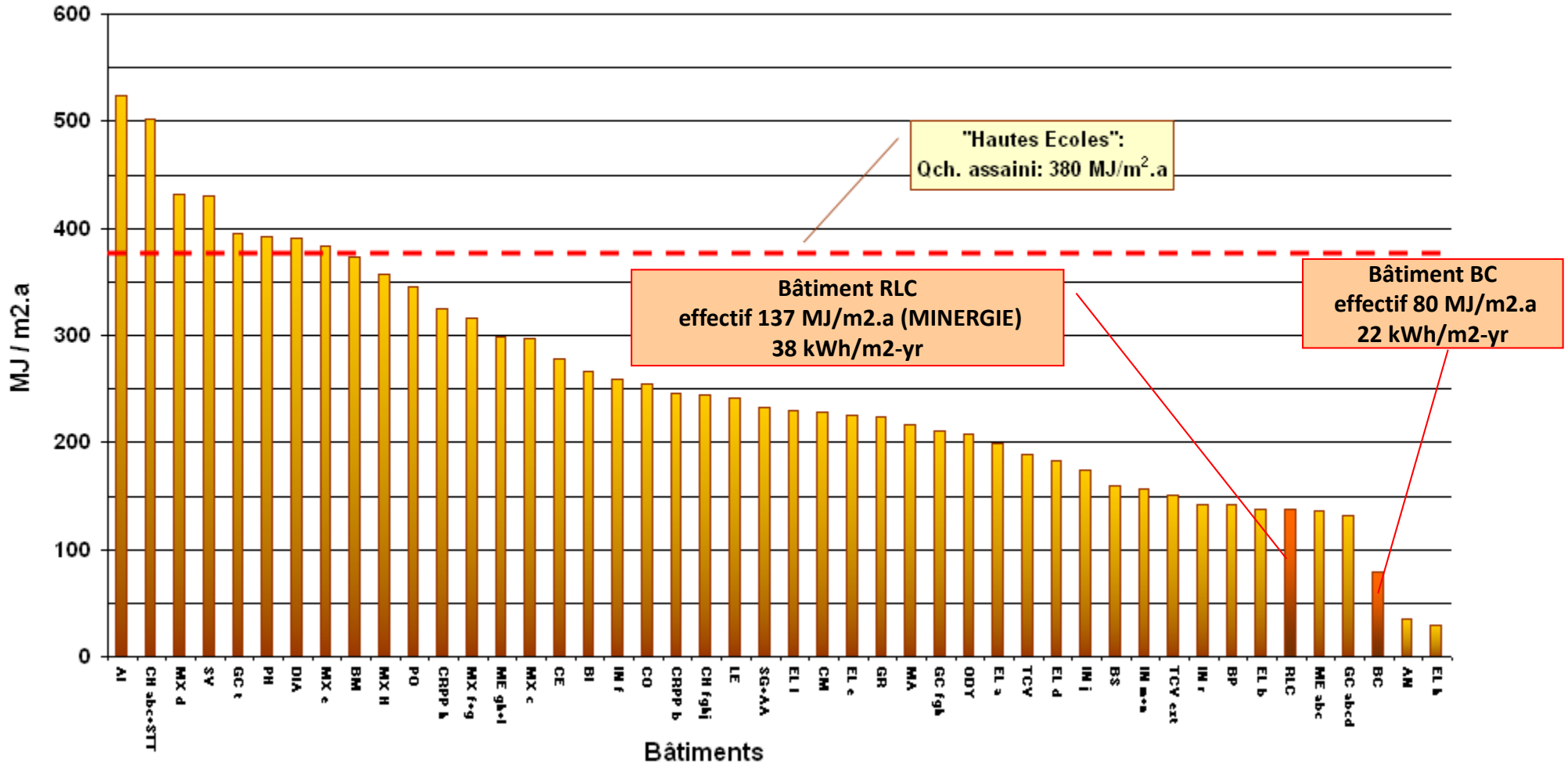
- Roof and ground insulation
- Exterior blinds
- Day-lighting and natural ventilation
- Thermal pumps that use the adjacent lake water for cooling
- **Measured heat energy consumption (2009) 38.1 kWh / m^2**

Indice énergétique chaleur des bâtiments 2009

Moyenne EPFL en 2009: 264 MJ/m2.a (en 2008: 281 MJ/m2.a)

(Consommation annuelle de chaleur (Qch) par m2 de surface brute)

Références: valeurs indicatives
SIA 180/4: "L'indice de dépense d'énergie"
SIA 380/1, éd. 1988: "L'énergie dans le bâtiment"



Effin'Art
The Art of Energy Efficiency

Archives départementales du Nord Reconstruction des magasins

Département Du Nord

Direction Générale Adjointe de l'Enseignement, du Patrimoine et des Infrastructures
Direction de l'Elaboration des Grands Projets
Direction de l'Action culturelle

- Dévelopment of the "Programme technique et climatique" (collaboration with specialist of building programming)
  - Exigence n°1: Concept énergétique global reposant sur le concept de bâtiment à énergie positive à haute performance énergétique → *zero fossile energy on the annual balance*
  - https://www.lemoniteur.fr/article/demarche-hqe-le-conseil-general-du-nord-passe-de-l-experimentation-a-la-grande-serie-avec-la-certification.1731009
    - Une simulation effectuée avec les bureaux d'études suisse Sorane et lyonnais Couzane a permis de mesurer la faisabilité du projet.

Le 1er bâtiment d'archives à énergie positive de France

Pour sauvegarder ses archives, stockées jusqu'alors dans un bâtiment vieillissant et devenu exigu, le Conseil Général du Nord a souhaité un bâtiment fonctionnel, adapté au tissu urbain et surtout respectueux de l'environnement.

Collectivités territoriales | Le 31 janvier 2013

Project performed by P. Jaboyedoff when employed by Sorane

Effin'Art
The Art of Energy Efficiency

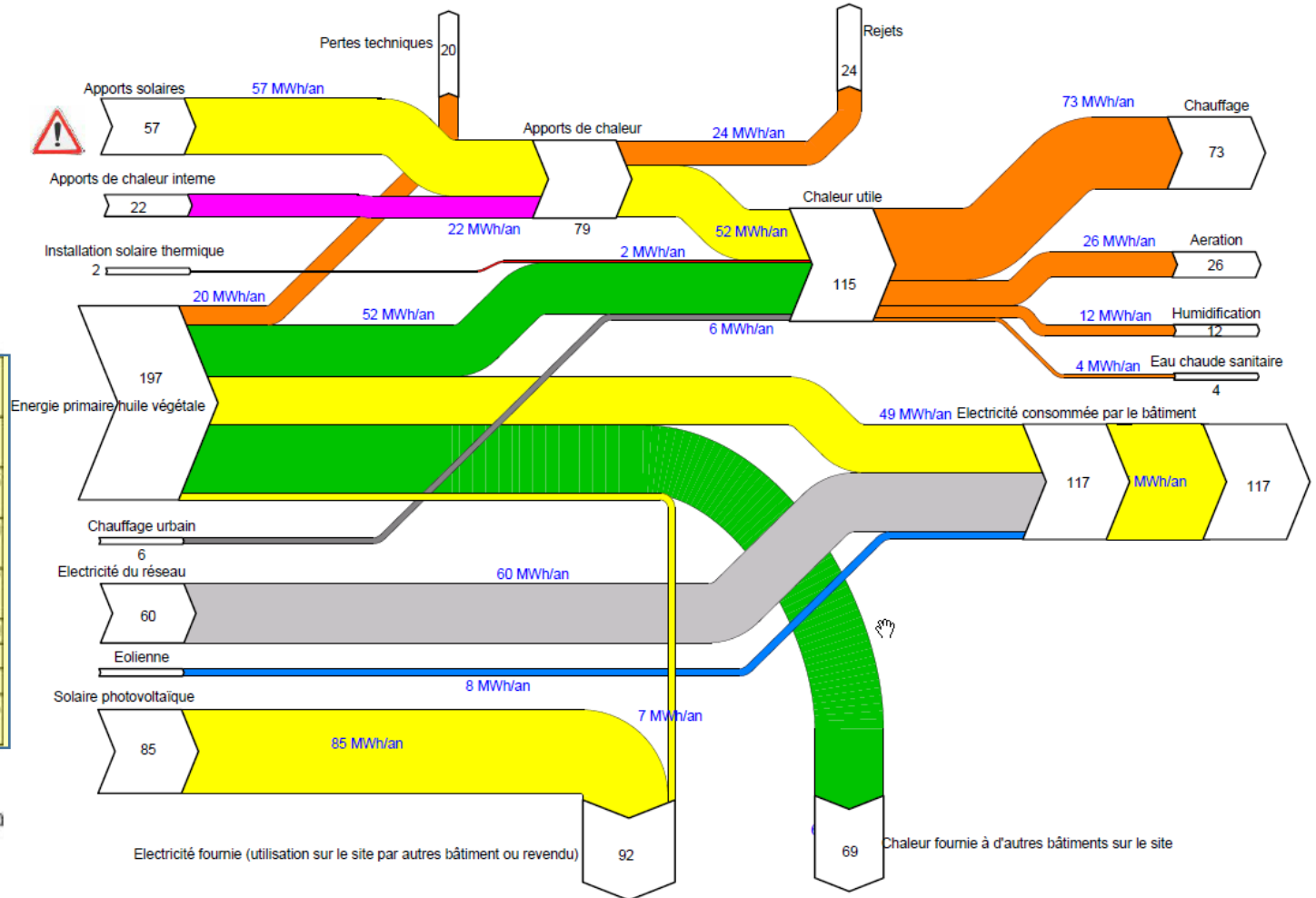
Archives départementales du Nord
Reconstruction des magasins

Conseil Général
Département du Nord

- *Translation of the proposals (5 candidates) into Sankey diagrams*
- *Analysis of the various branches (component predicted performances)*
- *«expert» reviewed value*
  - *By simple 1st order calculations*
  - *Simulation when needed*

	Valeurs originale du groupement		Valeur de contre-expertise	
	Energie finale	Energie primaire	Energie finale	Energie primaire
Electricité consommée depuis le réseau	-60	-155	-60	-155
Chaleur consommée non renouvelable	0	0	0	0
Electricité renouvelable fournie à l'extérieur	92	237	92	237
Chaleur fournie à l'extérieur	69	69	39	39
Bilan énergie positive		151		121
Ratio Energie Primaire fournie à l'extérieur/Energie primaire consommée		198%		178%

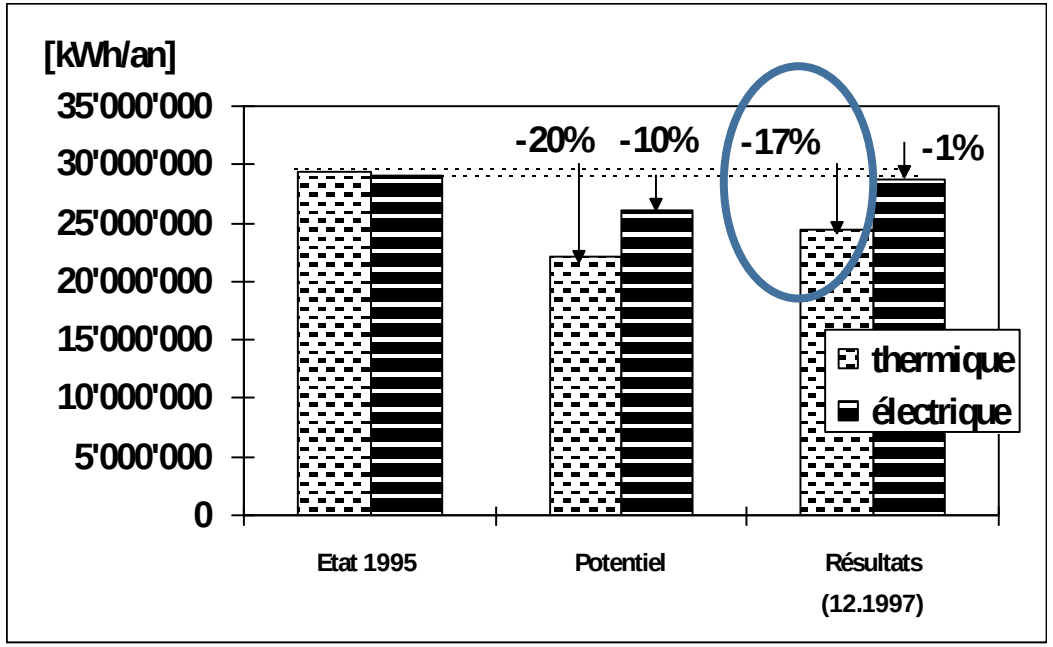
Commentaire:
Les apports de chaleur solaires sont nettement surestimés, cela entraine une demande d'énergie ch
plus importante. L'énergie chaleur à exporter diminue. Le bilan reste néanmoins positif.



Effin'Art
The Art of Energy Efficiency

CHUV (Lausanne) Energie 2000 programme

- Heat demand
  - Systematic control and adjustment of heating curve
- Ventilation
  - Reduction of humidity set points in 80 zones of the hospital
  - Reduction of air flow rate in 120 AHU's



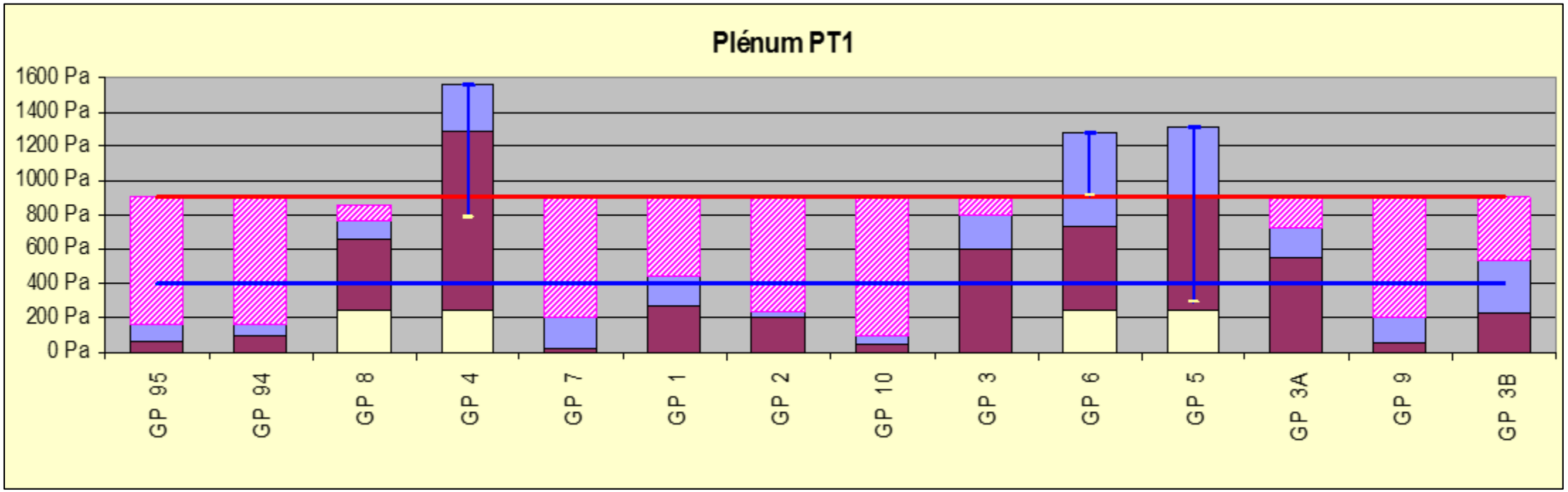
Project in charge P. Jaboyedoff when employed by Sorane

Centre hospitalier universitaire vaudois

ENERGHO: RESULTATS

Example: Optimizing pressure level in ventilations
→ Reduction ~225 MWh/yr

- Action 013 – Diminution de la pression des prétraitements d'air du BH



Centre hospitalier universitaire vaudois

Effin'Art
The Art of Energy Efficiency

Research Center Nestlé
Near Lausanne, Switzerland

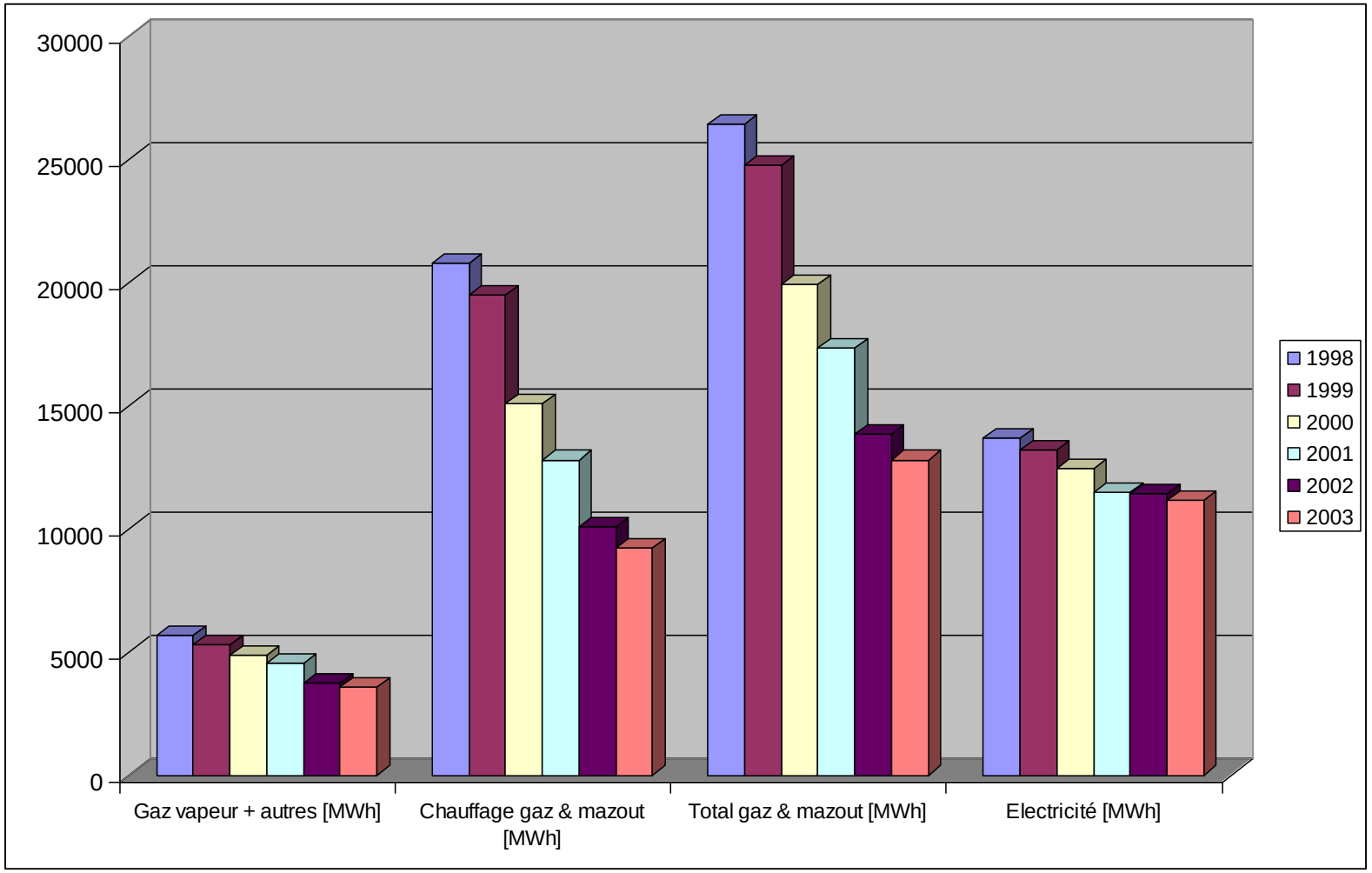
- 65000 m2 of floor area
- Energy Audit
- Continuous energy monitoring
- Energy management strategies development
- Assistance to the client in planning and implementation
- Studies and projects
- Very tight collaboration with the team
- Knoledge transfer (train and empower the local team to go on in the long run)

Project in charge P. Jaboyedoff when employed by Sorane

Effin'Art
The Art of Energy Efficiency

CRN Summary of energy consumption over the 5 years of intervention

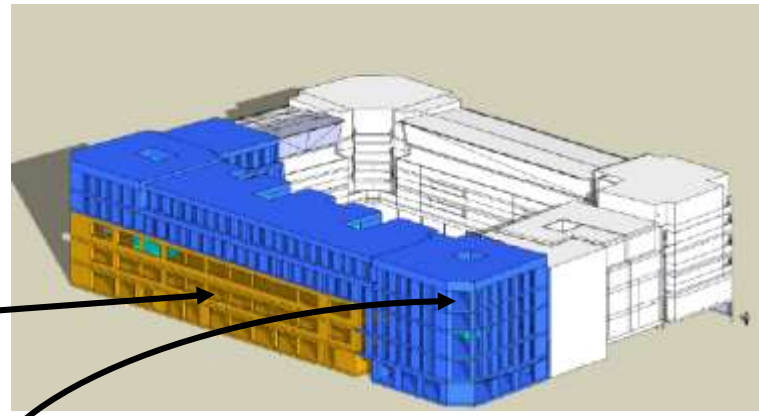
- Reduction of heat energy demand of 56 %
- Reduction of electrical consumption of 20%
- Equivalent to 5% of the total energy consumption of Nestlé in Switzerland

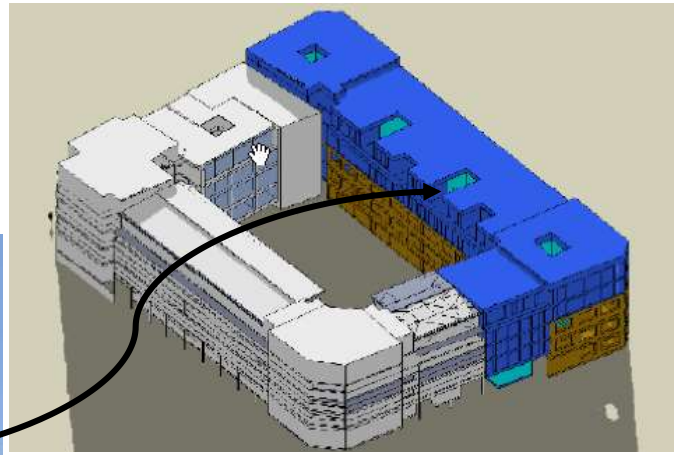


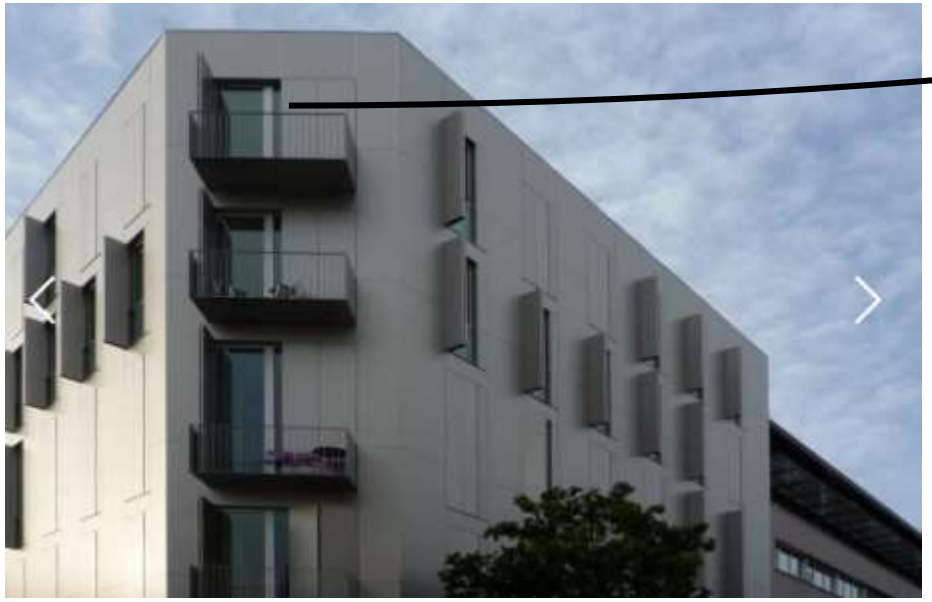
Effin'Art
The Art of Energy Efficiency

Les Marroniers, Retrofit+new residential with small commercial area

- Existing part, retroffited
- New
- Project
  - 760 m2 commercial
  - 6050 m2 dwellings
  - Designed and built for Minergie-ECO label (obtained VD-068-ECO)





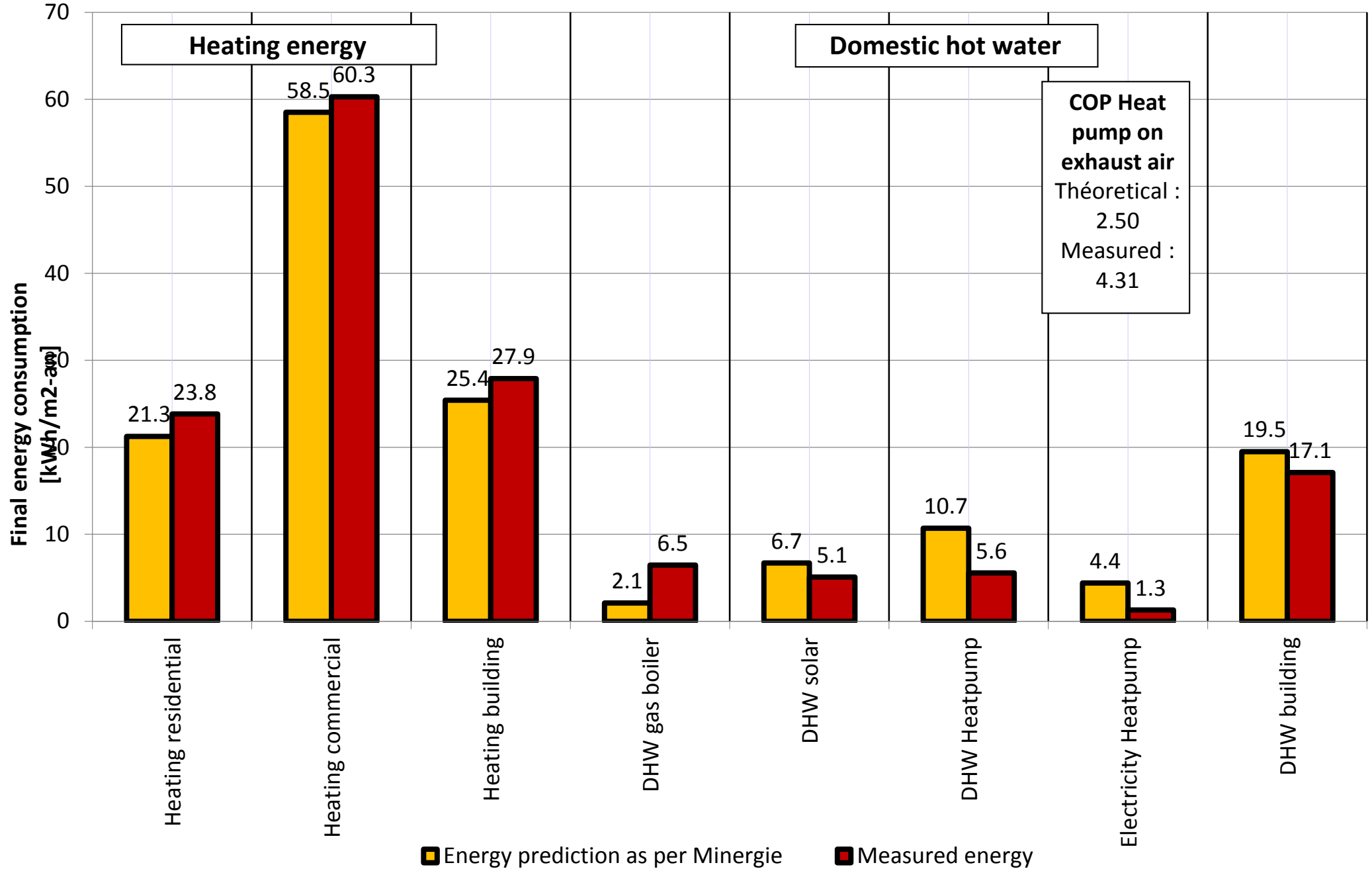


Project performed partly by M. Blanc when employed by Sorane

Effin'Art sàrl
03.11.2016

Effin'Art
The Art of Energy Efficiency

Marronniers - non corrected measurement:predictions vs. measurement
5 octobre 2015 until 4 octobre 2016

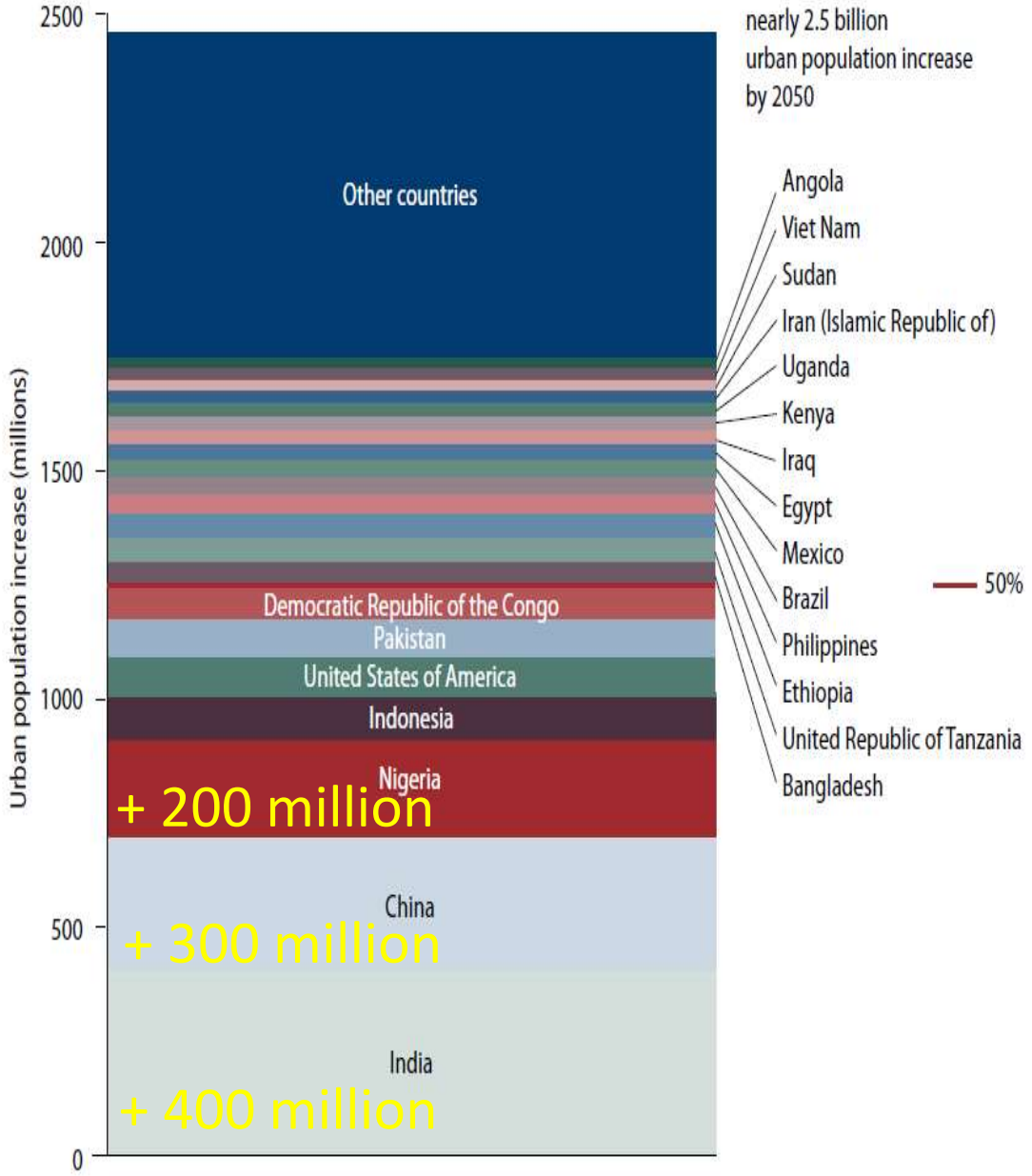


Effin'Art
The Art of Energy Efficiency

Urbanisation in India Scenarios, some numbers

- Between 2014 and 2050, the urban areas area are expected to grow by 404 million people in India[1] electrical energy for residential to become largest demand in India
- In India, air conditioning is below 10% in residential buildings
- The financial means and human resources in Building Science Research is very limited

Figure 7.
Contribution to the increase in urban population by country, 2014 to 2050



1. United Nations, Department of Economic and Social Affairs, Population Division (2014). *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).*

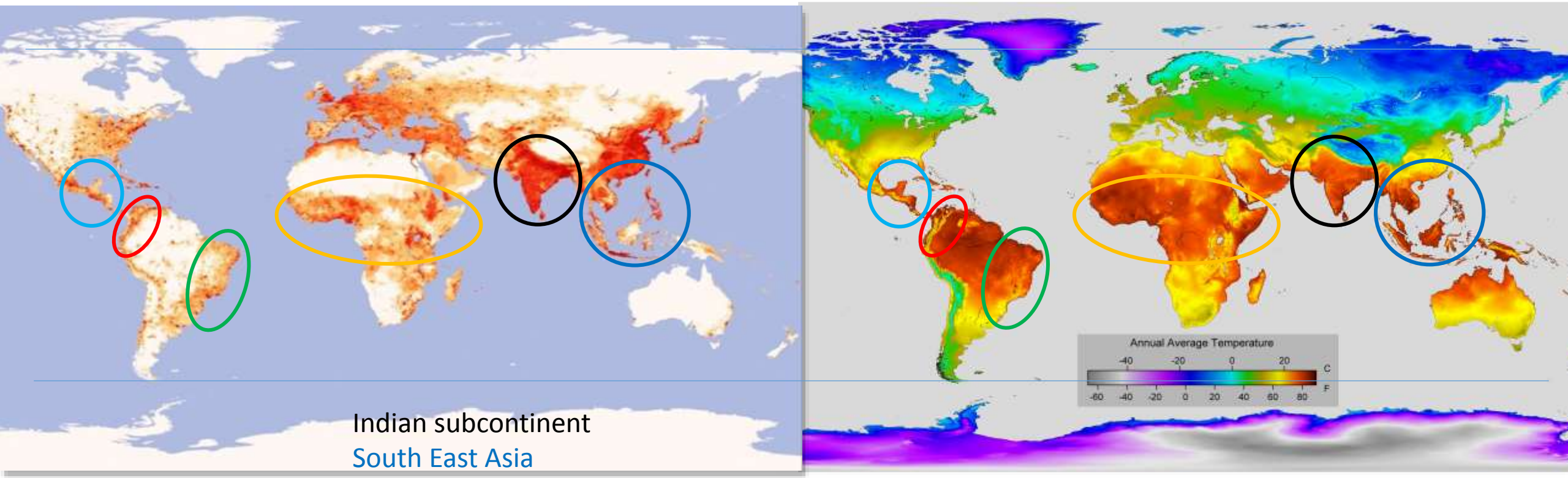
Effin'Art
The Art of Energy Efficiency

The situation in the hot climate emerging countries and needs for the next 2-3 decades

- ~2 Billions people leave in hot countries and do not have cooling in their dwellings
- Issues
  - Most of new buildings built do not include any system beyond water supply and electric power
  - Ceiling fans, Evaporative cooling or Air conditioner have to be bought and installed at the occupant cost
  - This situation will take decades to change in countries like India
- What actions could help ?
  - Research on reduction of heat gains in non AC buildings
    - Low cost passive designs to reduce significantly heat gains
    - Local urban planning (macro, meso, micro) for wind access for natural ventilation
      - Develop specifically open source CFD tools for design (eg. OpenFOAM)
    - Assisted cross ventilation (wind driven, high efficiency fans)
    - Low cost decentralized very small capacity cooling (evaporative cooling integration, and with dehumidification where needed …)

Effin'Art
The Art of Energy Efficiency

Coincidence of population density (left) and annual average temperature (right) with little mechanical cooling ratio



Indian subcontinent
South East Asia
Africa
Mexico
Venezuela, Columbia, Ecuador, Peru
Brasil

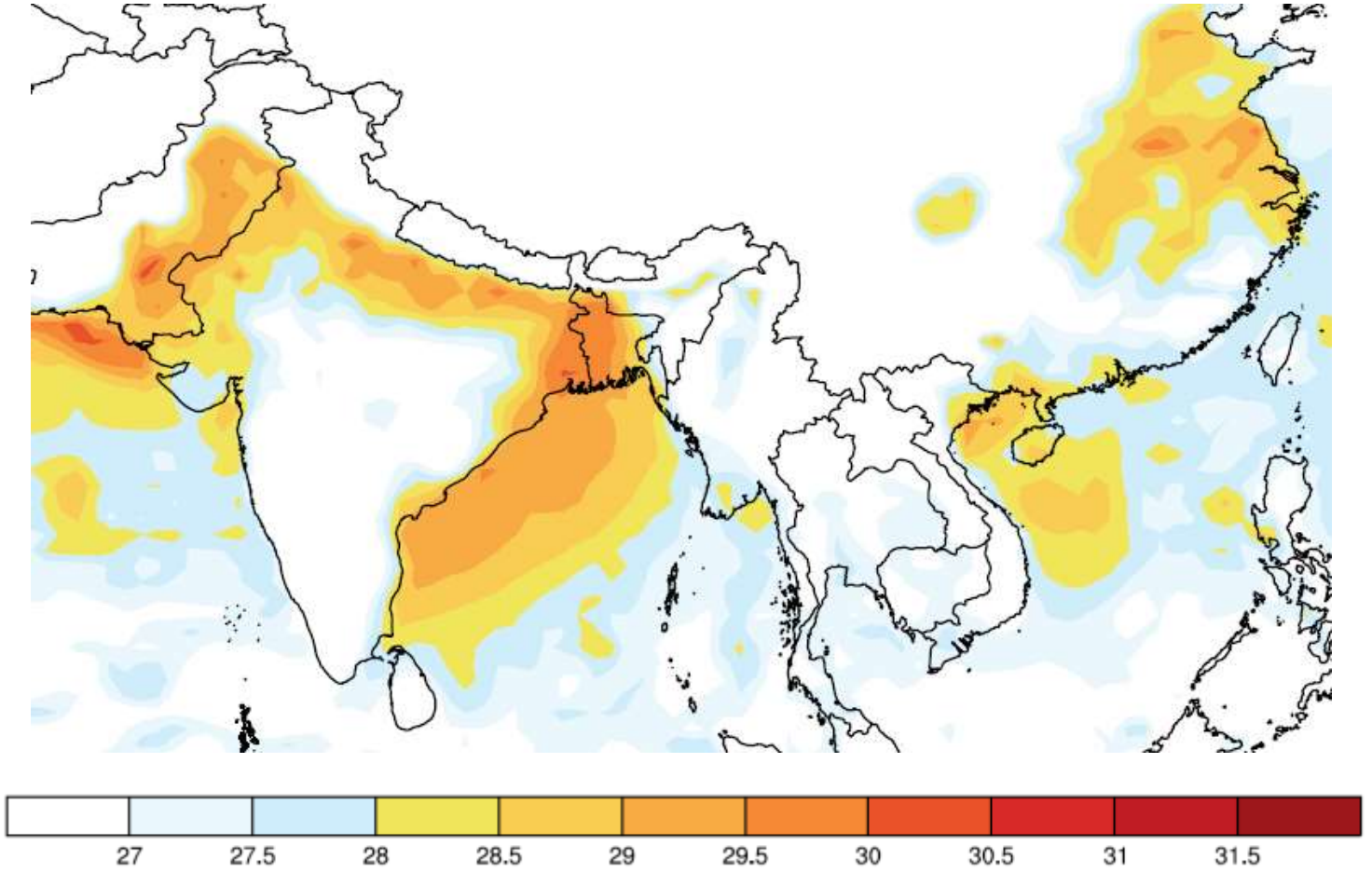
~50% of world population suffers from heat (<10% with mechanical cooling)

☹

Effin'Art
The Art of Energy Efficiency

Recent paper: "Deadly heat waves projected in the densely populated agricultural regions of South Asia"

- Spatial distribution of highest daily maximum wet-bulb temperature, TWmax (Wet-bulb) (°C), in modern record (1979–2015)
- However, three extensive regions, where values exceed 28°C, are observed: southwest Asia around the Persian/Arabian Gulf and Red Sea, South Asia in the Indus and Ganges river valleys, and eastern China
- If ambient air TW exceeds 35°C (typical human body skin temperature under warm conditions), metabolic heat can no longer be dissipated. Human exposure to TW of around 35°C for even a few hours will result in death even for the fittest of humans



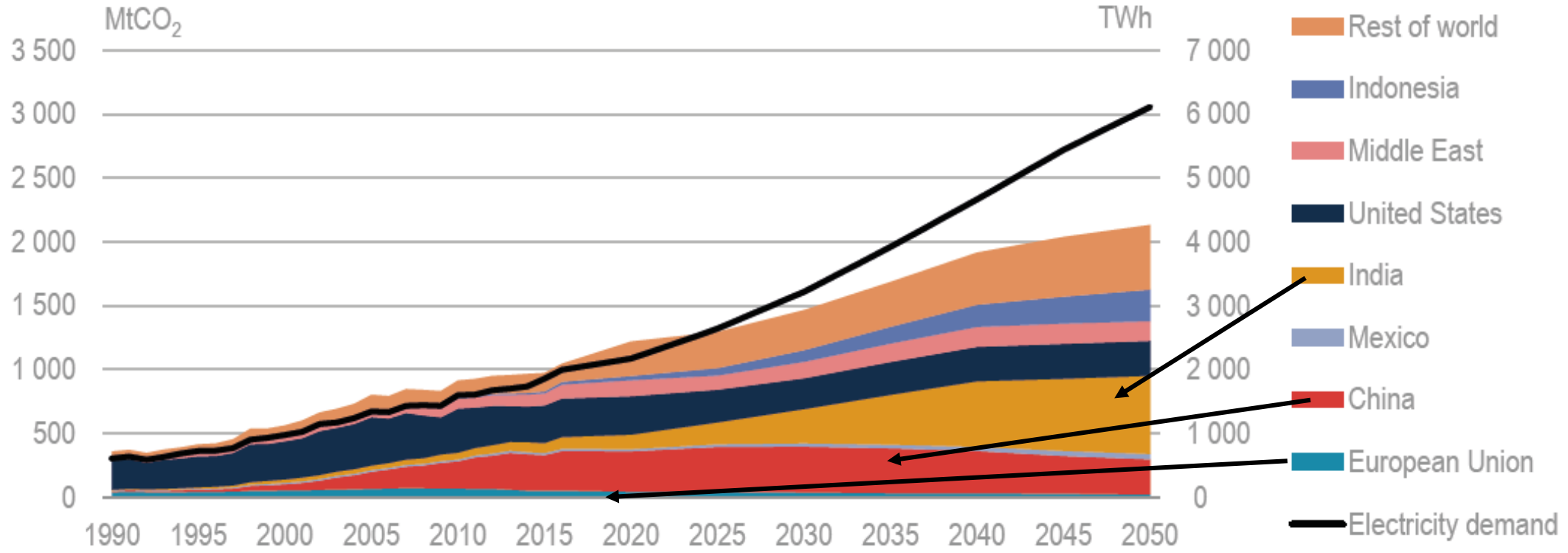
Deadly heat waves projected in the densely populated agricultural regions of South Asia
Eun-Soon Im,1* Jeremy S. Pal,2* Elfatih A. B. Eltahir3†
Im, Pal, Eltahir, Sci. Adv. 2017;3: e1603322 2 August 2017

Effin'Art
The Art of Energy Efficiency

One of the largest issues is cooling

The Future of Cooling Opportunities for energy-efficient air conditioning

Figure 3.13 • Electricity demand from space cooling and resulting CO_2 emissions in the Baseline Scenario



Key message • India and Southeast Asia account for the largest shares of the growth in CO_2 emissions from air conditioning, due to demand growth and reliance on coal-fired generation.

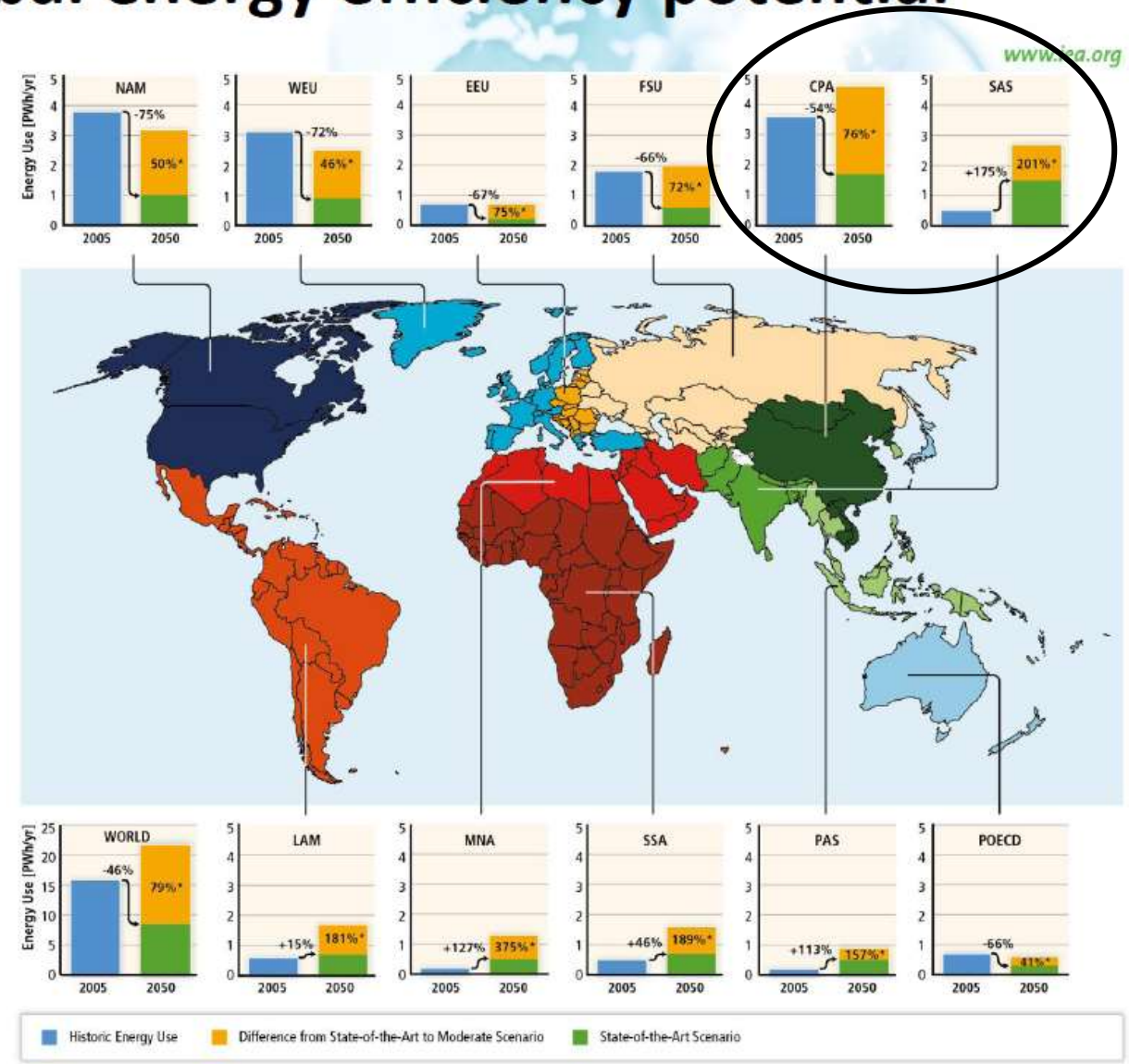
Effin'Art
The Art of Energy Efficiency

International Energy Agency
Secure Sustainable Together

Global energy efficiency potential

- Historic energy use
- State of the art scenario
- Difference between moderate and state of the art scenario

- **Potential to reduce final energy use for space heating & cooling through energy efficiency**



Source: IPCC 2014

Effin'Art
The Art of Energy Efficiency

Case Study: Aranya Bhawan, Jaipur

https://www.beepindia.org/case-studies-n-resources/

BEEP
BUILDING ENERGY EFFICIENCY PROJECT

Aranya Bhawan is the new office building of the Rajasthan Forest Department in Jaipur, inaugurated in March 2015.

Effin'Art
The Art of Energy Efficiency

Aranya Bhawan: BEEP Design Charrette (December 2012)

BEEP BUILDING ENERGY EFFICIENCY PROJECT

BEEP Integrated Design Charrette was held in December 2012, adopting a collaborative working approach between the client, RSRDC & the architect.

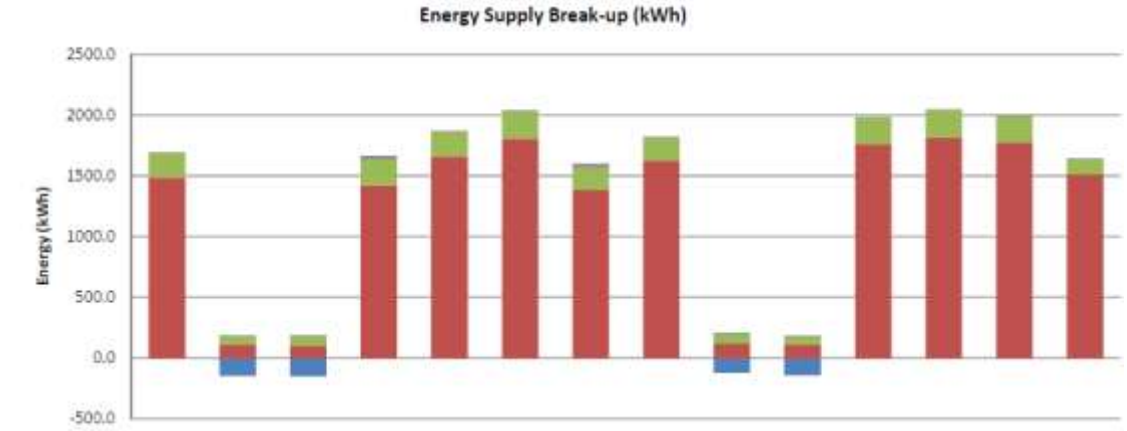
- **Client:** Rajasthan Forest Department
- **Executing Agency**: Rajasthan State Road Development and Construction Corporation Ltd. (RSRDC)
- **Architects:** Mathur, Ugam and Associates

As at the time of charrette, the orientation and building massing was already finalized; the focus was more on envelope & HVAC measures

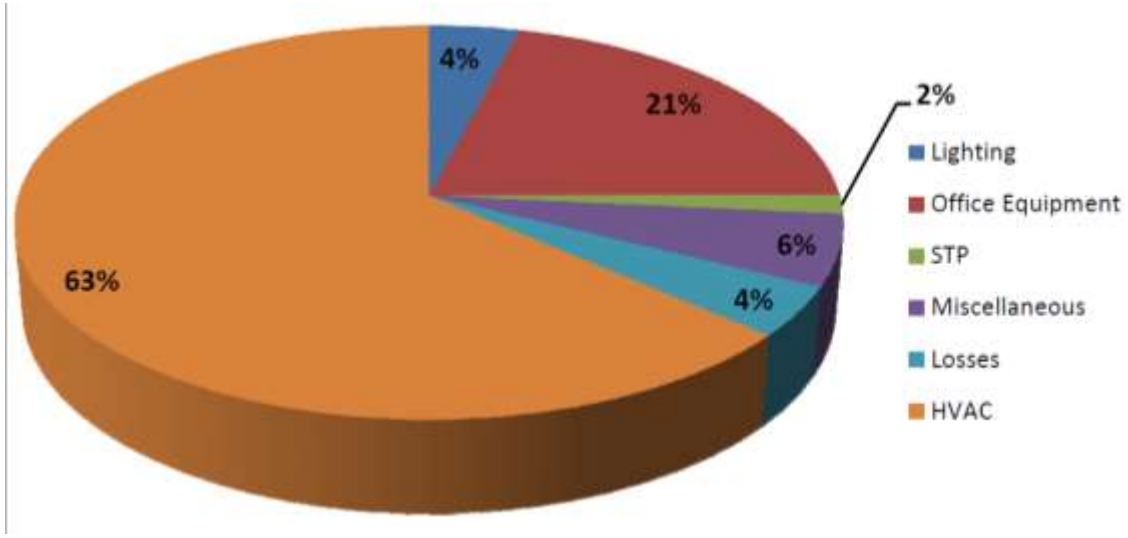
Effin'Art
The Art of Energy Efficiency

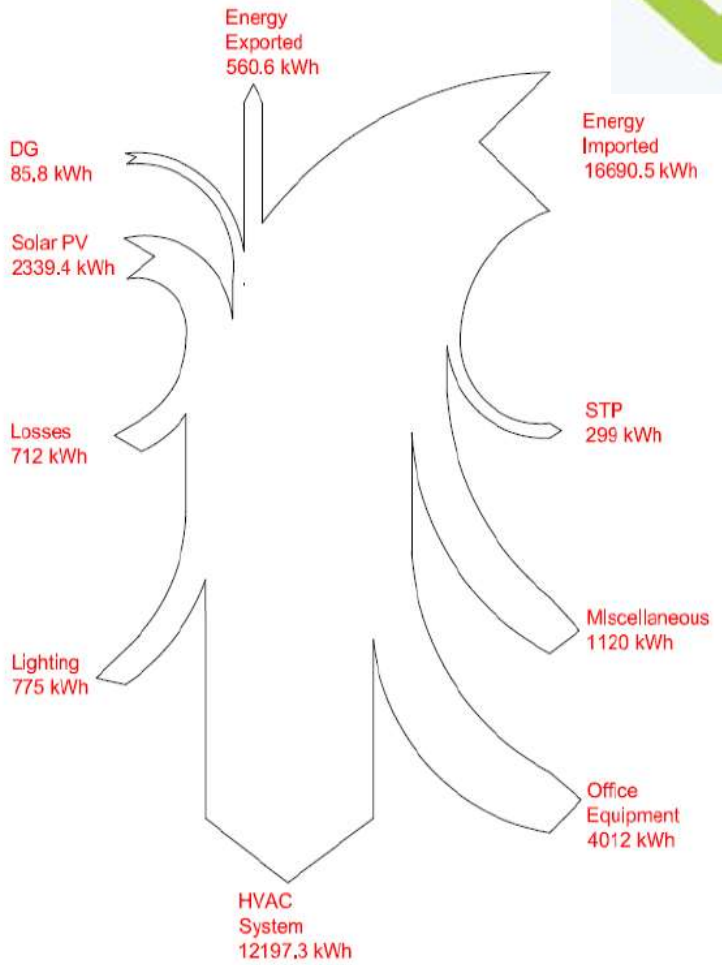
Monitoring results Aranya Bhawan Detailed audit (winter and summer)

BEEP
BUILDING ENERGY EFFICIENCY PROJECT



	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May
DG	3.5	3.4	3.2	20.9	3.6	3.5	21.5	5.8	3.4	3.5	3.3	3.4	3.5	3.3
Solar	204.0	68.9	83.0	224.0	204.0	228.0	192.0	192.0	86.1	65.4	220.0	228.0	216.0	128.0
Grid	1485	112.5	101.8	1419.3	1661	1806.5	1384.4	1624.3	119.1	112.9	1759	1815.2	1775.5	1514
Energy Export	0.0	-147.1	-149.0	0.0	0.0	0.0	0.0	0.0	-121.9	-142.6	0.0	0.0	0.0	0.0

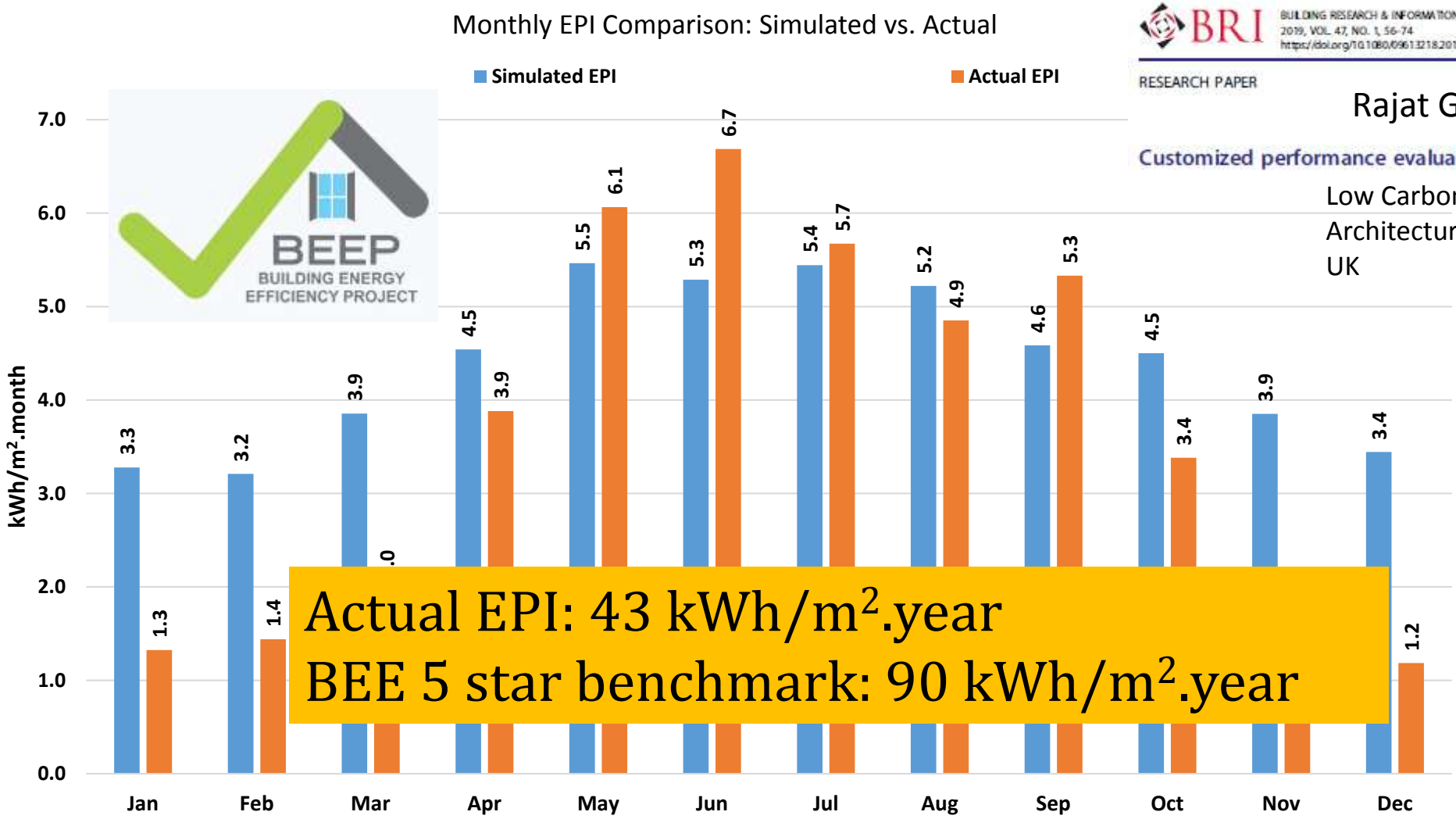




Energy flow (Sankey Diagram) for the Summer Monitoring

Effin'Art
The Art of Energy Efficiency

Electricity Consumption: Simulation & Actual (Electrical consumption of the site)



Actual EPI: 43 kWh/m².year
BEE 5 star benchmark: 90 kWh/m².year

BRI BUILDING RESEARCH & INFORMATION
2019, VOL. 47, NO. 1, 56-74
https://doi.org/10.1080/09613218.2019.1525962
Routledge Taylor & Francis Group

RESEARCH PAPER OPEN ACCESS

Rajat Gupta

Customized performance evaluation approach for Indian green buildings

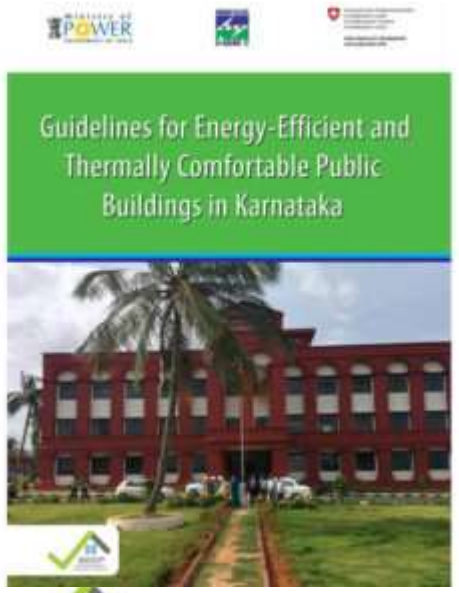
Low Carbon Building Research Group, School of Architecture, Oxford Brookes University, Oxford, UK

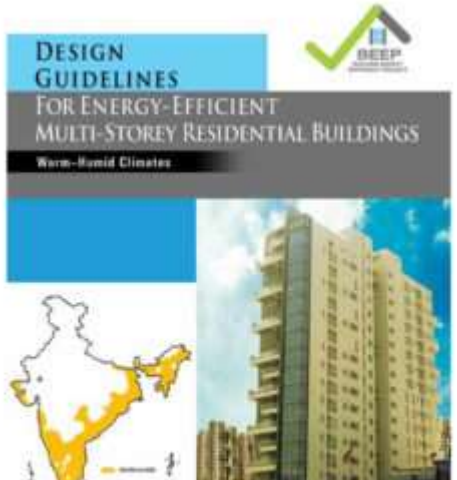
"only one study was found (Bhanware, Jaboyedoff, Chetia, Maithel, & Reddy, 2017) that went beyond the above studies by including a design and system installation review, seasonal energy monitoring for two different seasons, and data logging of electricity distribution with IEQ spot measurements"

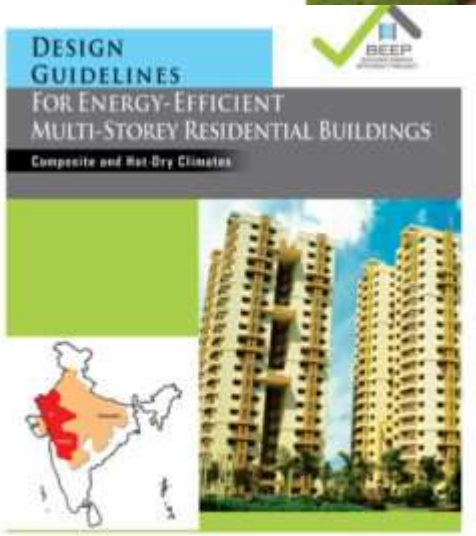
Effin'Art
The Art of Energy Efficiency

BEEP (Building Energy Efficiency Project) in India (2007-2021)

- Project between the Swiss and Indian government
- Main objectives contribute towards improvement of energy efficiency of bui
- Main components
  - Support and capacity building of project developers (public and private)
  - Development of technologies and market (insulation testing, external movable s
  - Policy support for development and implementation of building codes
  - Outreach
    - Information to media
    - Training
    - Publications, guidelines, building codes







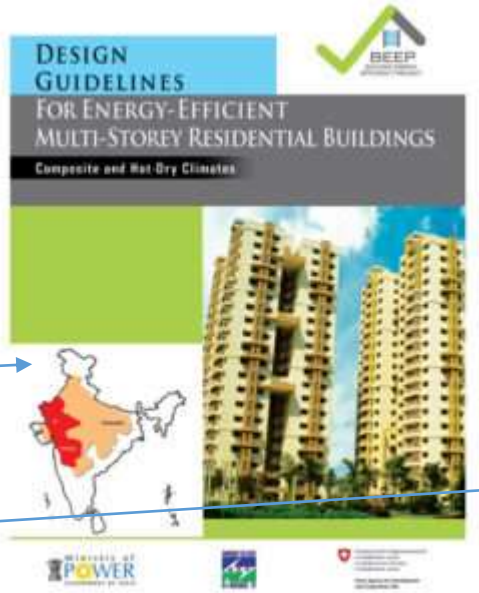
Design guidelines for multi-storey residential buildings

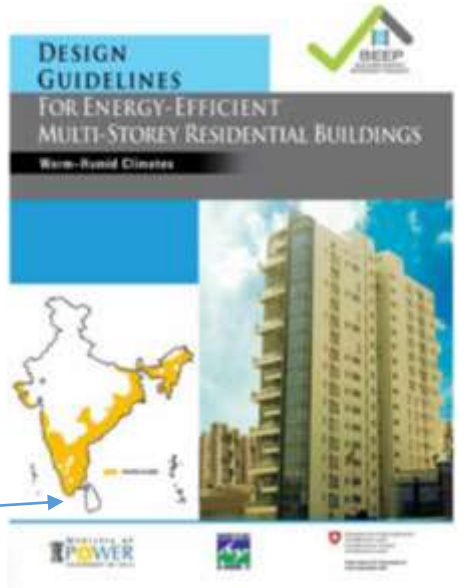
Design guidelines for multi-storey residential buildings

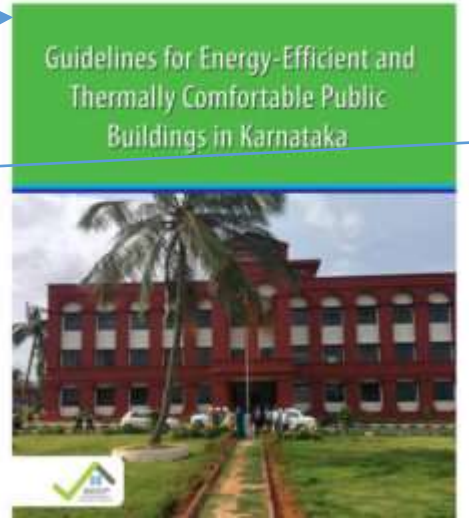
Effin'Art
The Art of Energy Efficiency

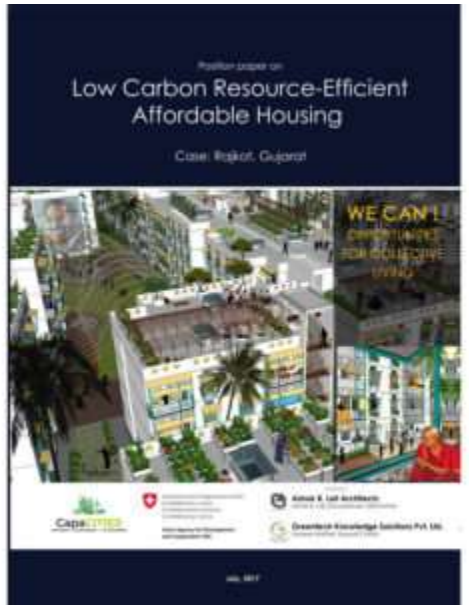
Largerly distributed publications

- Design guidelines for multi-storey residential buildings (composite and hot and dry climates (mentioned in the India INDC at COP21 in Paris)
- Design guidelines for multi-storey residential buildings (warm and humid climates
- Guidelines for energy efficient public buildings in Karnataka (60 millions inhabitant)
- Position paper on Low Carbon Resource-Efficient Affordable Housing
- Building Codes for Residential Buildings 2018 Part I: Building Envelope (all India) (to be released)







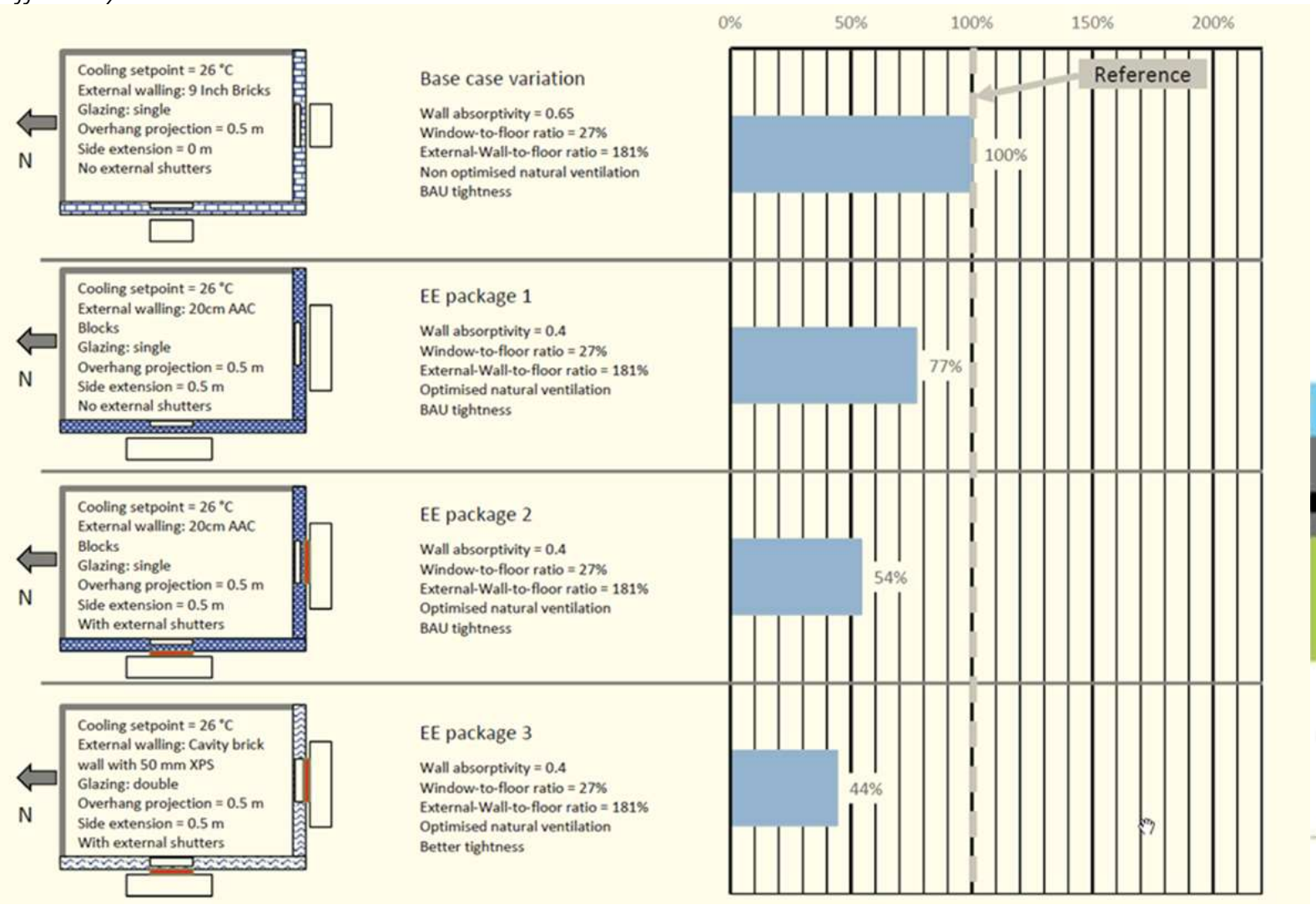


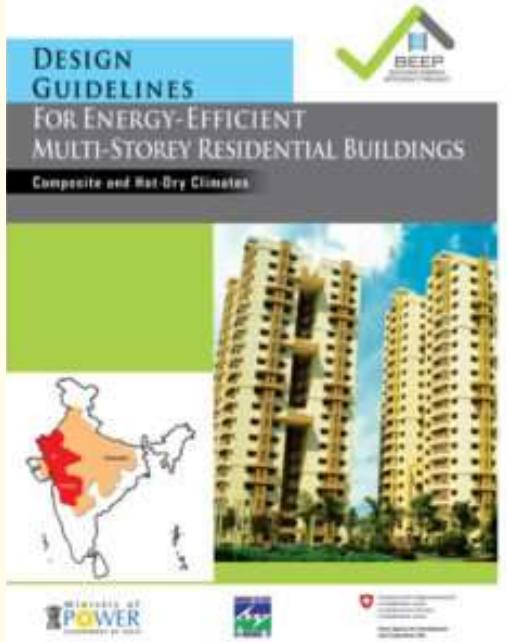
Effin'Art
The Art of Energy Efficiency

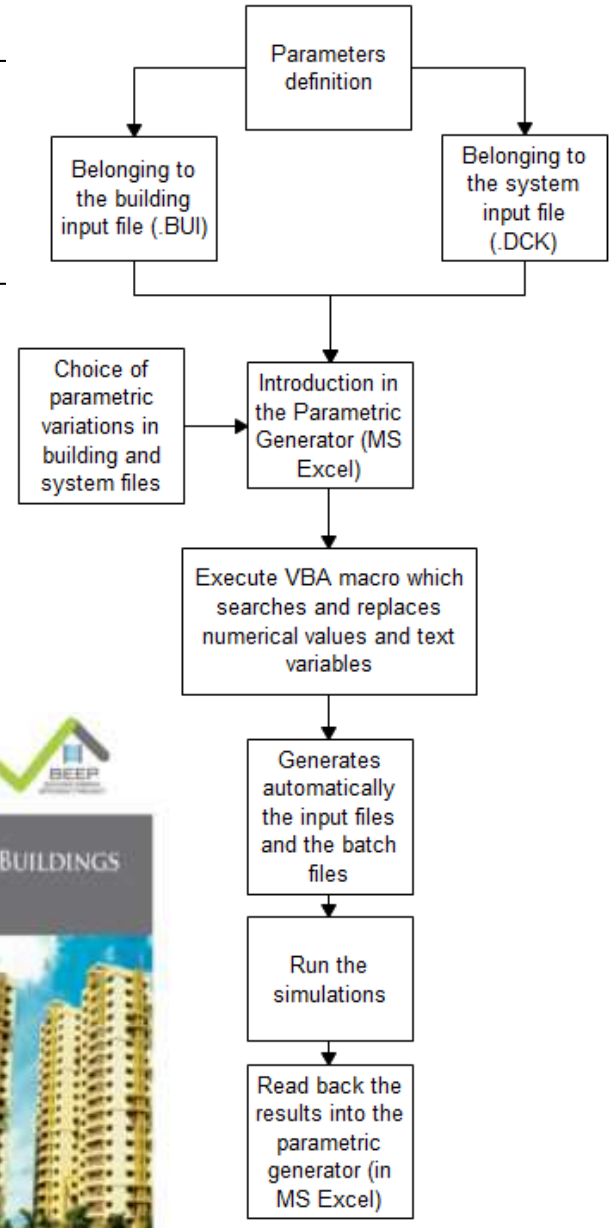
- Methodology was published at IBPSA 2015

PARAMETRIC ANALYSIS USING DYNAMIC ENERGY SIMULATION TOOLS TO EVALUATE THE PERFORMANCE OF BUILDING ENVELOPE IN THE RESIDENTIAL BUILDINGS OF COMPOSITE CLIMATIC REGION OF INDIA

Pierre Jaboyedoff1, Kira Cusack2, Prashant Bhanware3, Kanagaraj Ganesan3, Saswati Chetia3, Sameer Maithel3
1Effin'Art, Switzerland, info@effinart.ch, www.effinart.ch, IBPSA Switzerland Board Member
2Effin'Art, Switzerland, info@effinart.ch, www.effinart.ch
3Greentech Knowledge Solutions Pvt. Ltd, sameer@gkspl.in, www.gkspl.in







Effin'Art
The Art of Energy Efficiency

Building Code development

- Literature search an visit to Singapore
- Development of the Code principles
- Identification of typology of buildings
- Development of automated parametric studies
  - Preparation of EnergyPlus files
  - Collection of results for development of the multi-linear regressions (coding developped in house)

BEEP
BUILDING ENERGY EFFICIENCY PROJECT

Abstract submitted for IBPSA 2019: Development of RETV (Residential Envelope Transmittance Value) Formula for Cooling Dominated Climates of India for the Proposed Energy Conservation Building Code for Residential Building (ECBC-R)

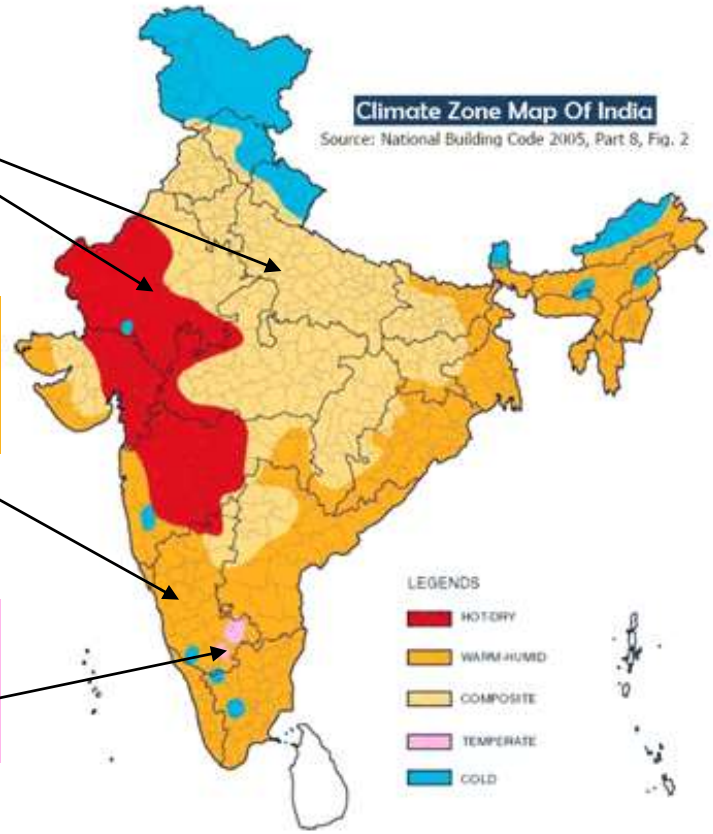
Effin'Art
The Art of Energy Efficiency

RETV Formula (40'000 EnergyPlus simulations)
Residential Envelope Transmittance Value

$$RETV_{Composite.Hot-Dry} = 6.11 * (1 - WWR) * U_{wall} + 1.90 * WWR * U_{win} + 70.94 * WWR * SHGC_{effective}$$

$$RETV_{Warm.Humid} = 5.19 * (1 - WWR) * U_{wall} + 1.34 * WWR * U_{win} + 66.70 * WWR * SHGC_{effective}$$

$$RETV_{Temperate} = 5.27 * (1 - WWR) * U_{wall} + 0.95 * WWR * U_{win} + 78.92 * WWR * SHGC_{effective}$$



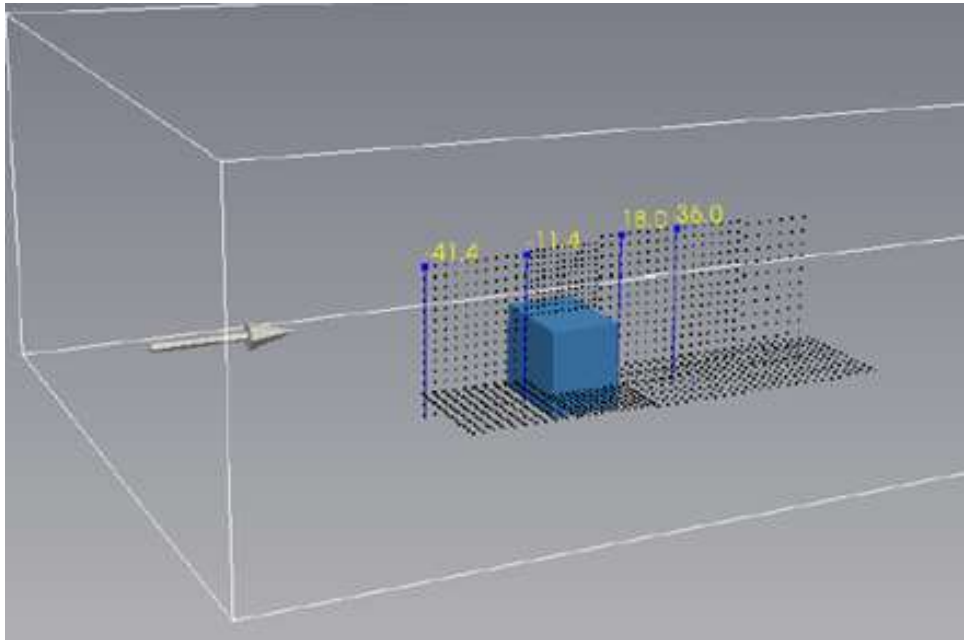
BEEP
BUILDING ENERGY EFFICIENCY PROJECT

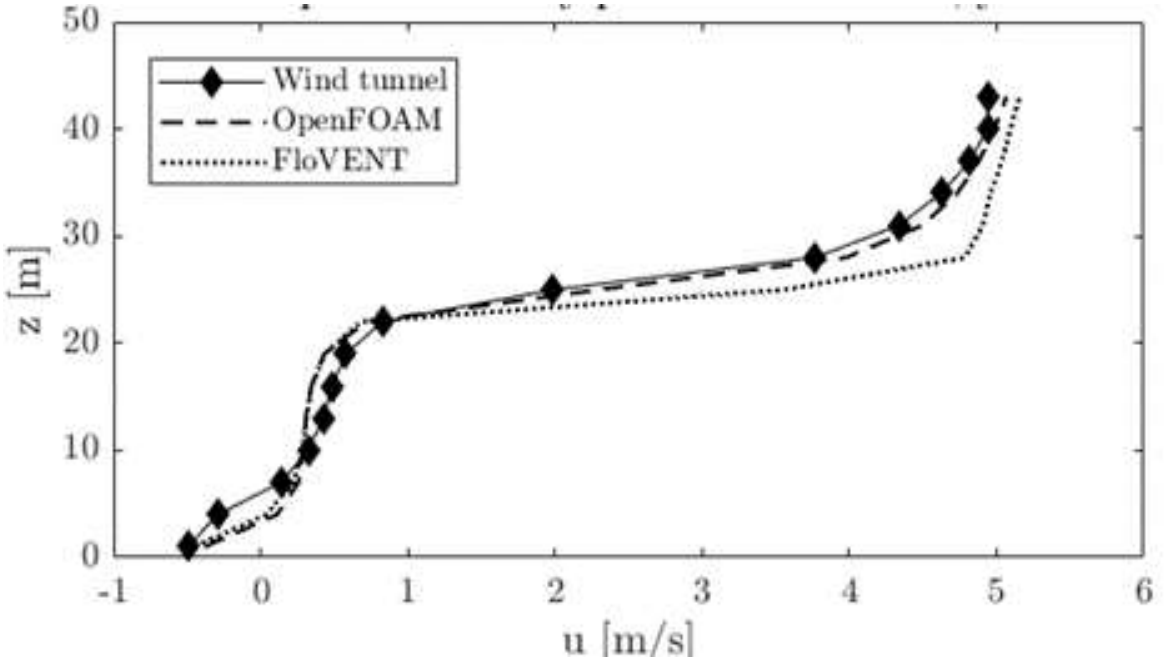
Effin'Art
The Art of Energy Efficiency

Development of an easy version of OpenFOAM for large projects wind driven natural ventilation assessment (early testing of the feasibility) in collaboration with HES-SO Valais

BEEP
BUILDING ENERGY EFFICIENCY PROJECT

- Wind tunnel data compared with OpenFOAM and Flovent



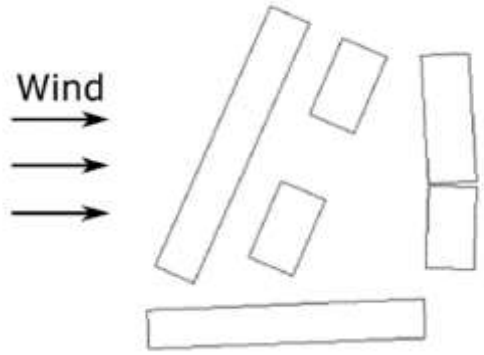


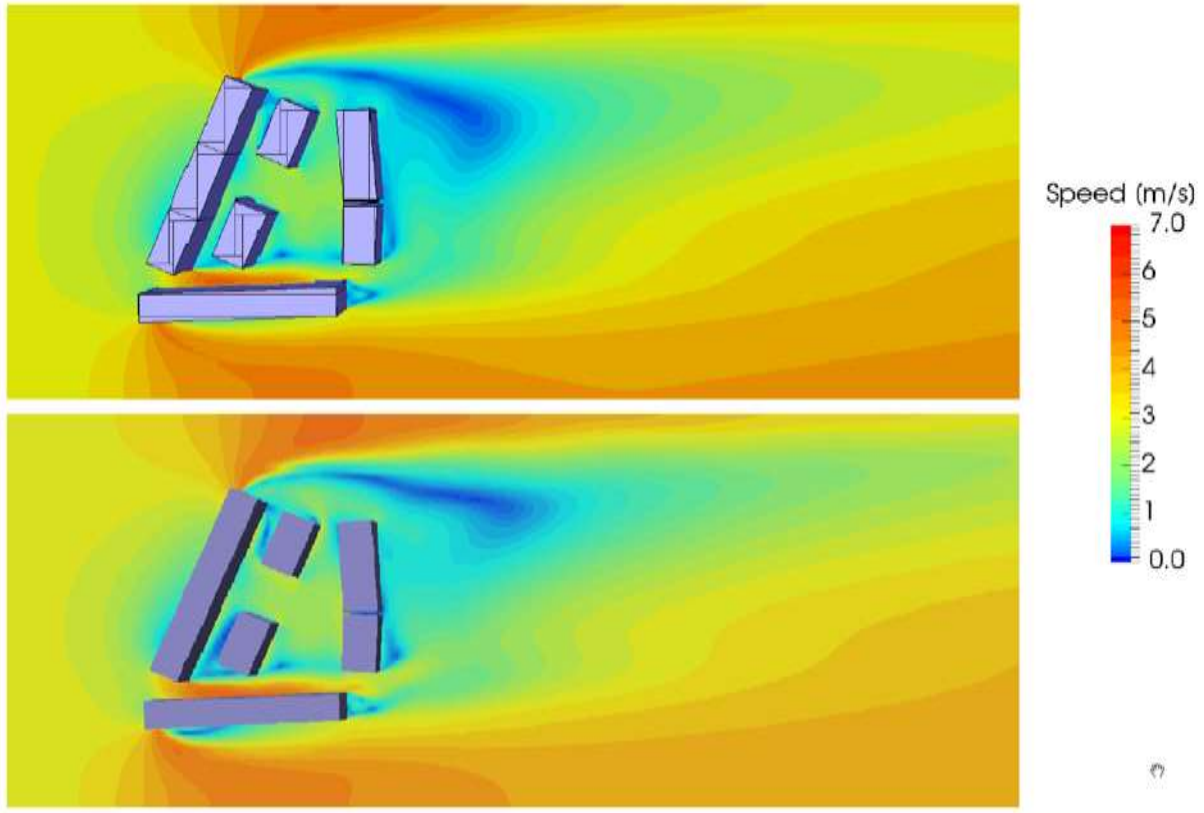
Effin'Art
The Art of Energy Efficiency

Development of an easy version of OpenFOAM for large projects wind driven natural ventilation assessment (early testing of the feasibility) in collaboration with HES-SO Valais

BEEP
BUILDING ENERGY EFFICIENCY PROJECT

- Inter-program comparison
  - 1800 dwelling project
  - Indore, India





Velocity magnitude contours in the z = 10 plane. Top: simulated with FloVENT. Bottom: simulated with OpenFOAM

Effin'Art
The Art of Energy Efficiency

Contribution to the IEA4 training programmes

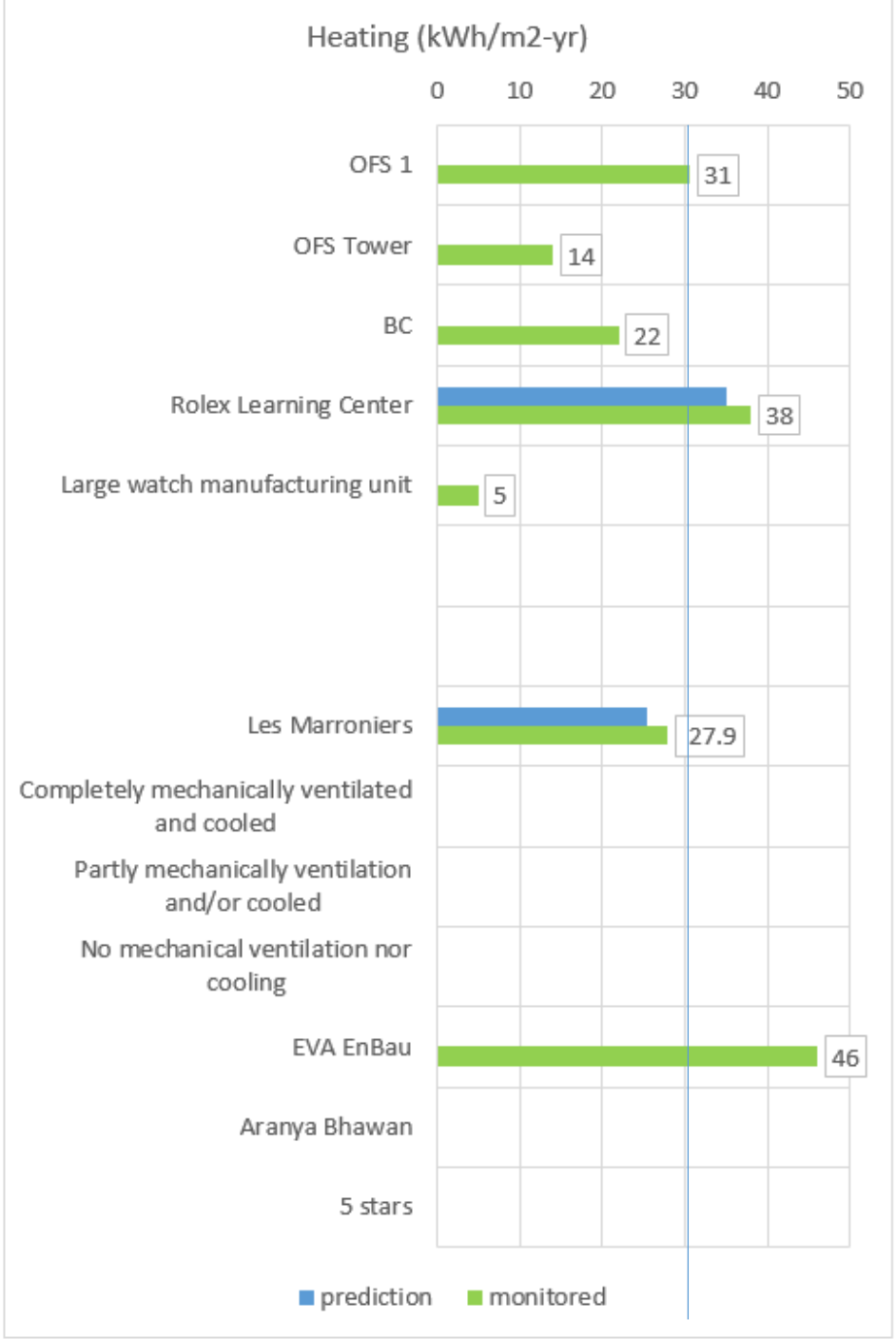
Energy Efficiency in Emerging Economies (E4) Programme

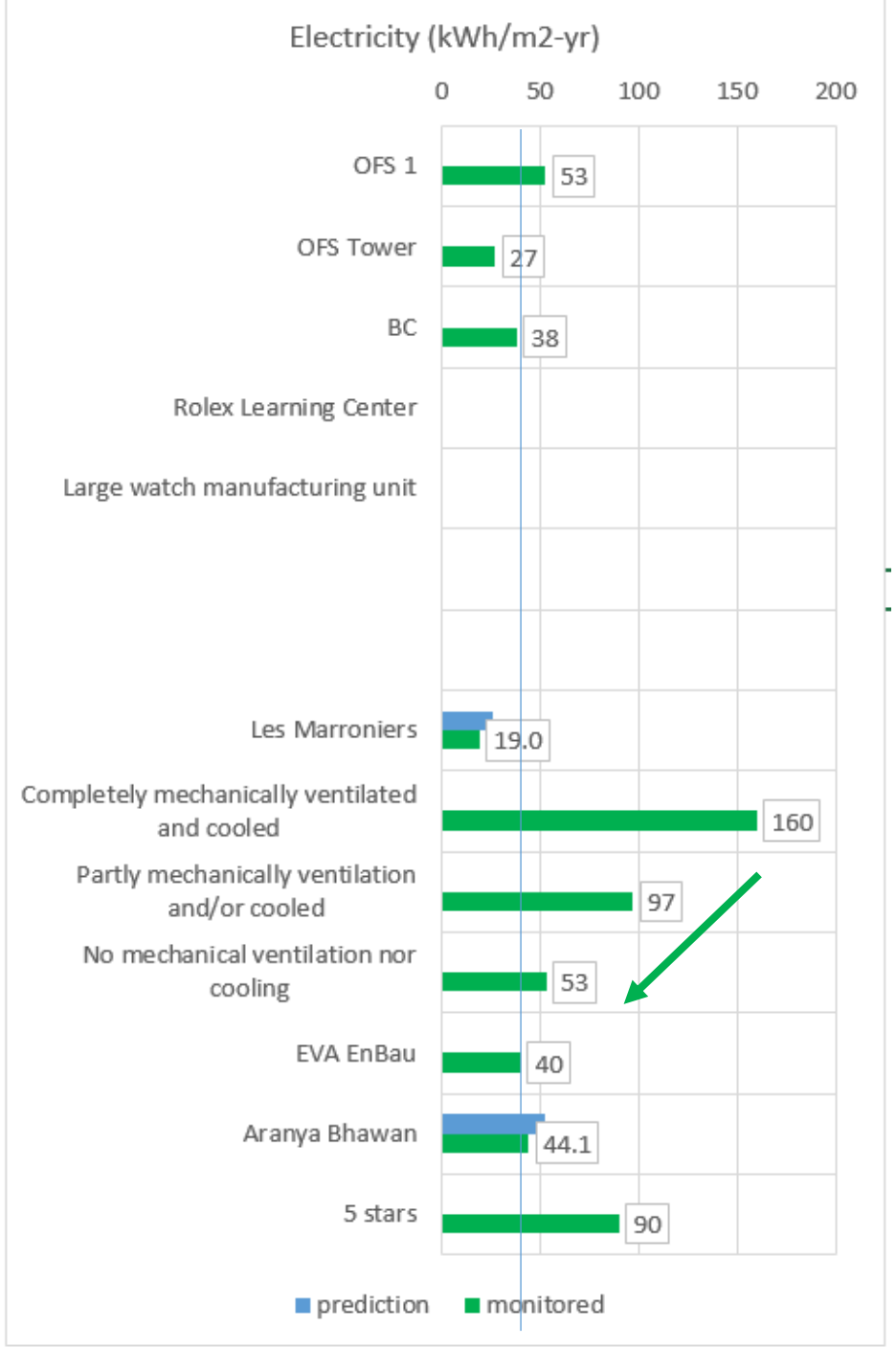
- BEEP Project identified by IEA
- Paris 2018
- Support to IEA4 for the development of a building design module
- Intervention during the various presentations

Effin'Art
The Art of Energy Efficiency

Summary Buildings monitoring

- The simpler, the better
- Complex technology in the building is not the solution
- If you observe the fundamentals, then the results are normally good





Effin'Art

The Art of Energy Efficiency

- Thank you ☺