David Reinhard:: Technical Building Infrastructure :: Paul Scherrer Institut

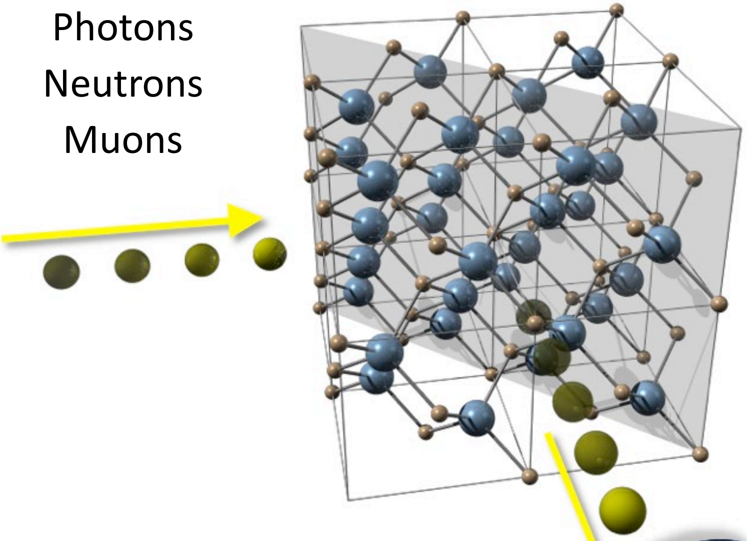
Energy optimisations
Implemented at accelerators and infrastructure at PSI

ESSR Grenoble, 29.9.2022

Large Research Facilities at PSI

Research at large facilities

Photons
Neutrons
Muons

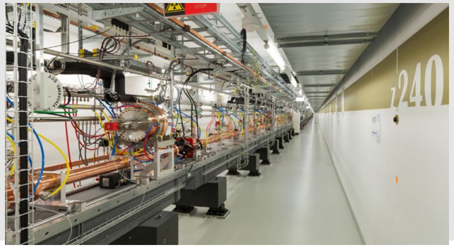


Microscopic insights into materials

Synchrotron Light Source SLS

Spallation Neutron Source SINQ

Muon Source SμS



Free Electron Laser SwissFEL

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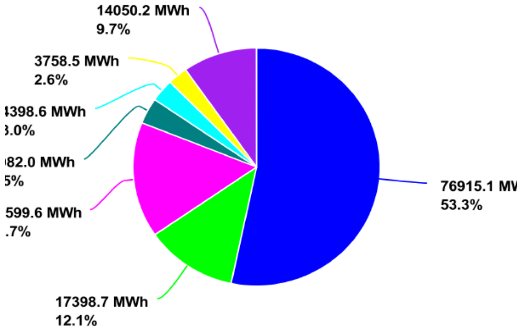
Key Figures

PSI funds (global budget)	300	MCHF
External funding	100	MCHF
Staff (heads)	2200	
• Externally financed	700	
• Doctoral students	310	
• Apprentices	100	
External users: people / visits	1500* / 2500*	per year
Number of scientific publications	1300 (17 % of which high impact)	per year
PSI employees with teaching duties at both ETH and universities	100	
Patient visits (proton therapy treatment)	5800	per year

*corona-related decrease -50% appr.

PSI`s Energy consumption (2021)



	Standort	Datenpunktbeschreibung	Summe	Einheit
(blue)	WEHA	HIPA Energie gesamt [MWh]	76'915.093	MWh
(green)	OSFA SwissFEL	SwissFEL Energie gesamt [MWh]	17'398.735	MWh
(magenta)	WSLA SLS	SLS Energie gesamt [MWh]	22'599.563	MWh
(teal)	WTSD	PROSCAN Energie gesamt [MWh]	5'081.991	MWh
(cyan)	WSHA Sultan	SULTAN Energie gesamt [MWh]	4'398.555	MWh
(olive)	OEAA PANDA	PANDA Energie gesamt [MWh]	17.899	MWh
(yellow)	PSI West	PSI West Rest Energie [MWh]	3'758.539	MWh
(purple)	PSI Ost	PSI Ost Energie (Büro, Labor und Infrastruktur) [MWh]	14'050.223	MWh

Total Power Consumption: 143 GWh

Total heat consumption: 5.7 GWh

Efficiency Measures driven by PSI Energy Mission and Federal Energy Law

PSI Energy Mission Statement

- PSI institute supports the role model function for efficient use of energy as a member of the Swiss government initiative "Exemplary Energy and Climate"
- During planning, construction, operation and renovation the aspect of energy efficiency is considered as a general guideline.
- Renovation programs at the accelerator facilities enable older components to be replaced with new, efficient and energy-optimised parts. Aspects of energy efficiency should serve as a general guideline for refurbishments, modernisations and replacement equipment.
- For new components, facilities and upgrade projects (e.g. SLS 2.0), particular attention is paid to energy efficiency (e.g. heat recovery, power electronics, magnets, high-frequency components).
- When planning new research facilities, a targeted energy minimisation and optimisation process should be carried out, preferably with the involvement of specialists.
- When procuring equipment, the most efficient options are generally preferred in terms of a life-cycle evaluation.

Legal Aspect: Large consumers are obliged to settle commitments (energy saving target) with Energy Agency

- Major consumers including end users with a heat consumption of more than 5 gigawatt hours (GWh) or an electricity consumption of more than 0.5 GWh per year and per consumption site – hence, PSI also meets this definition. Special legal requirements apply to these businesses, private companies and public institutions.
- Based on the cantonal Energy Act, the canton of Aargau enforces Grossverbraucher-Bestimmungen to increase energy efficiency in companies. In order to meet the requirements of the Major Consumer Article, PSI concluded a universal target agreement with the Energy Agency of the Swiss Private Sector (EnAW) back in 2013, and it now reports annually on the achievement of the target path.

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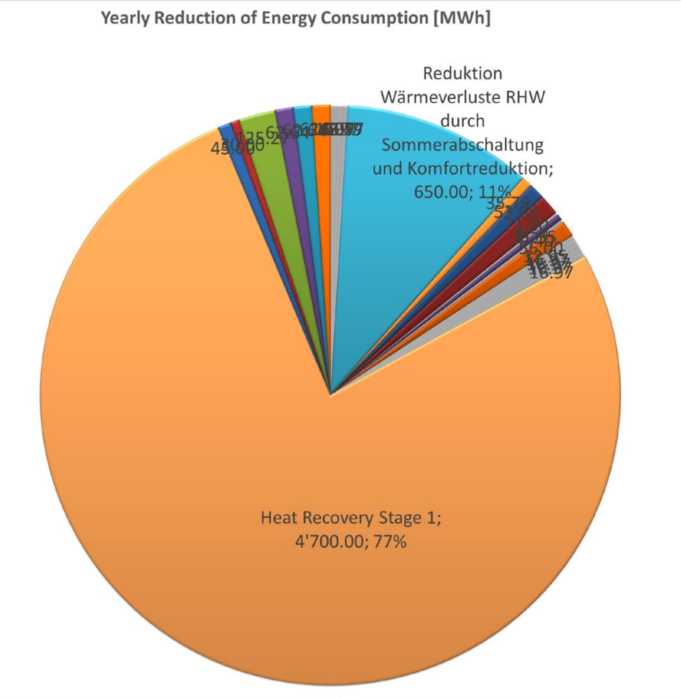
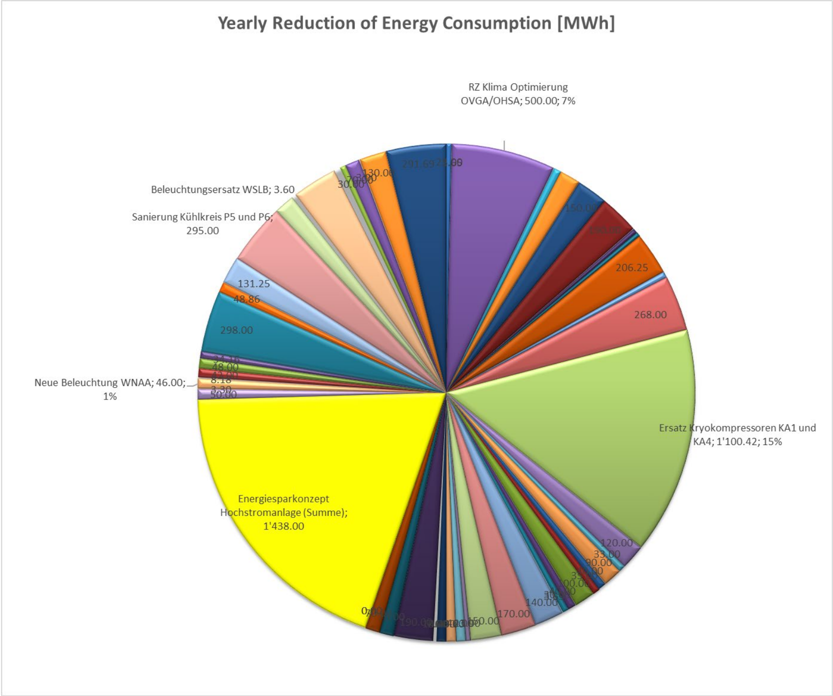
Results of Energy Efficiency Measures at PSI (2013-2020)

Number of measures and projects since 2013:	**75 (24 Heat; 61 Power)**
Yearly saving of el. energy:	**7.4 GWh (-6%)**
Yearly saving of heat consumption:	**5.2 GWh (-43%)**
Total yearly investments (average in 7 years):	**1.2 Mio CHF**
Total yearly savings:	**1 Mio CHF**
Total fundings awarded:	**3.6 Mio CHF (27 Projects)**
Total yearly refund of energy taxes:	**2 Mio CHF**



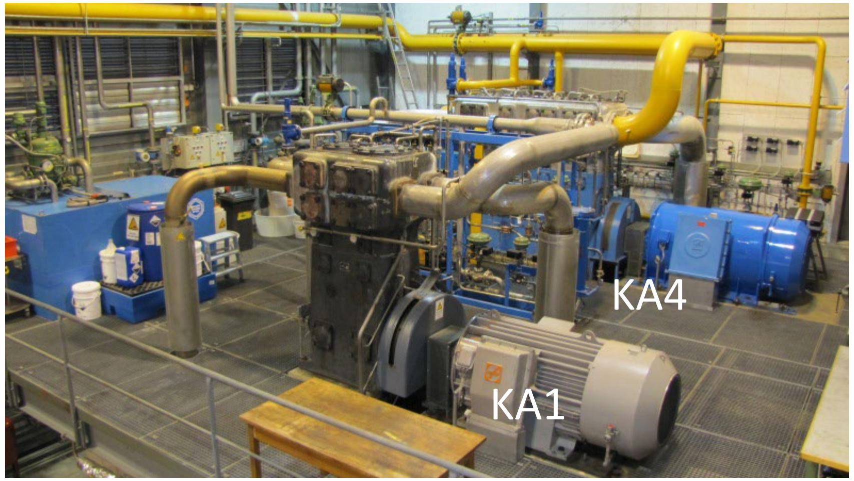
yearly saving of heat consumption: 5.2GWh (-43%)



yearly saving of el. energy: 7.4GWh (-6%)

Example 1, «Cryogenics» Replacement of HE-Compressors

- Two old but reliable piston compressors (cryogenic HE-Cycle in the filed of HIPA/SINQ) where replaced by 3 screw compressors
- Screw Compressors are more efficient and suited for continuous operation
- 270+570kW reduced to 160+500kW @ same boundary conditions, 6700 OH
- Yearly saving of 1.33GWh (appr. 1% of PSI consumption)



Piston Compressors

Screw compressors with oil removal system

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Example 1, «Cryogenics» Replacement of HE-Compressors

Side effects:

- Standardised components allow reduction of spare parts
- More space through optimised architectural layout
- Lower vibration (SLS)

Example 2, «IT» Server Virtualisation

Server Virtualisation (2009-2015)

- 1 server with virtualisation required 450W
- It replaces 35 conventional servers each consuming 200W
- Efficiency Increase of Factor 15!
- 550 Server 200W to 15 virtual 450W, Total Saving: 900MWh/a (45% from 2013)

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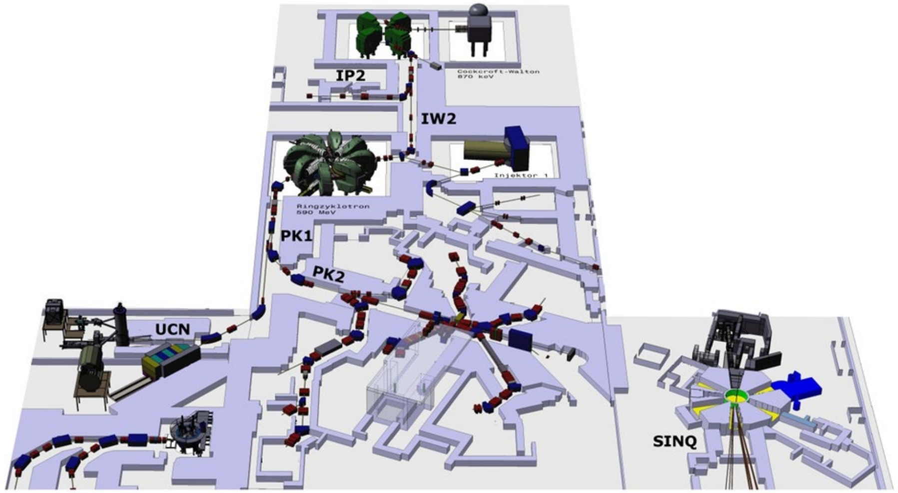
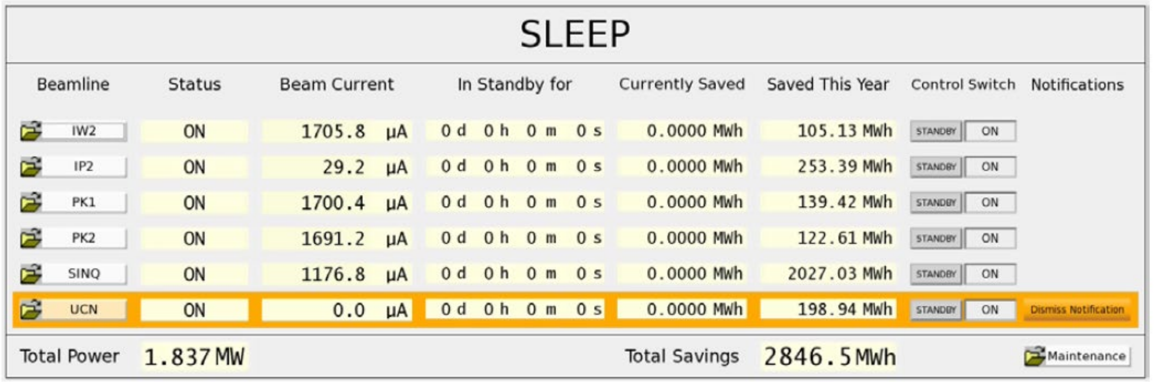
Example 3, «Operations», Sleep Mode Tool (HIPA+Proscan)

Figure 8: Distribution of 4 GWh HIPA Saving Potential.

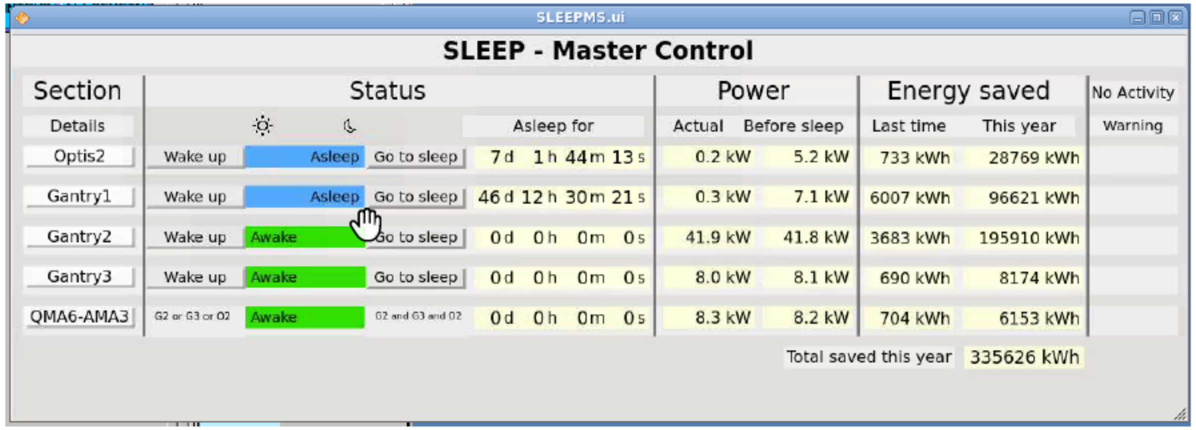


- The Facility contains 370 power consuming magnetic elements.
- In case of an outage the respective beamline shall be switched of since there is no use.
- The Sleep software provide the operators the possibility to switch on/off (Standby) various beamlines with a single click of a button. (signalisation in case of outages with no beam longer than 30 minutes).
- The amount of energy is saved and reported.
- The saving is vise versa with the reliability

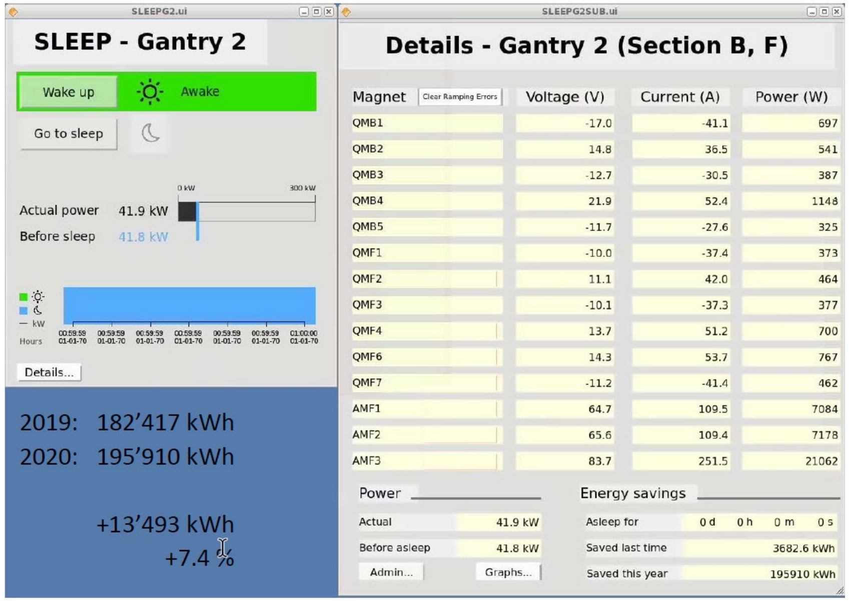
Example 3, «Operations», Sleep Mode Tool (HIPA+Proscan)



HIPA sleep overview beamlines current, status and savings



sleep Proscan overview



sleep Proscan detail view Gantry 2

Personal note: *Trivial but generic in various systems and applications. Observe and switch off what is not needed!*

Example 4, «Campus Infrastructure», high temp. water loop

Two Laboratories
- “OIPA” (Center for Radiopharmaceutical Sciences (CRS) to treat cancer)
- “OHLA” (HOTLAB laboratory to handle large quantities of radioactive materials)

  With a total of 100`000m3/h air exchange require humidification

Hot Lab

- A high temperature loop of a standby emergency heating unit is used to feed the steam generators.

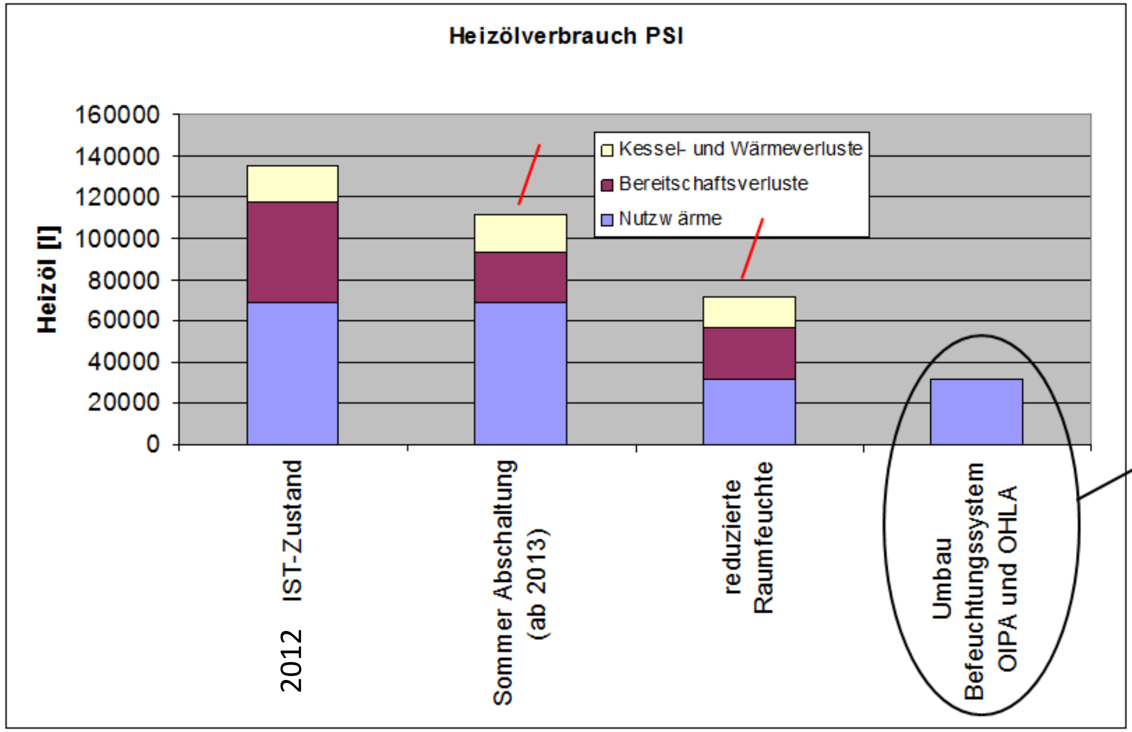
Oil storage tanks

Heating boilers 30MW for backup 80MW district heating system)

Steam generator

Steam injection

Example 4, «Campus Infrastructure», high temp. water loop



Weitere Option:
Niedertemperaturwärme
CO2-arm

(Refuna und geringer Anteil an PSI interner Abwärme da Bezug bei hohem Wärmeleistungs-bedarf)

→Investitionsintensiv

- Step 1: Reduction of standby losses (standby emergency kept with conceptual adaptations)
- Step 2: Reduction of Setpoint rel. humidity (less comfort)
- Yearly Savings: 65`000l (650MWh)

- Future Step 3: Switch to low temperature humidification system (high investment in conjunction with general refurbishment of ventilation unit)

Example 5, «Infrastructure», LED Light in Research Halls

LED Lightning WEHA, WNLA und WNHA (HIPA/SINQ)

- Yearly saving of 300MWh / 30kFr at more than double light intensity (300Lux)!

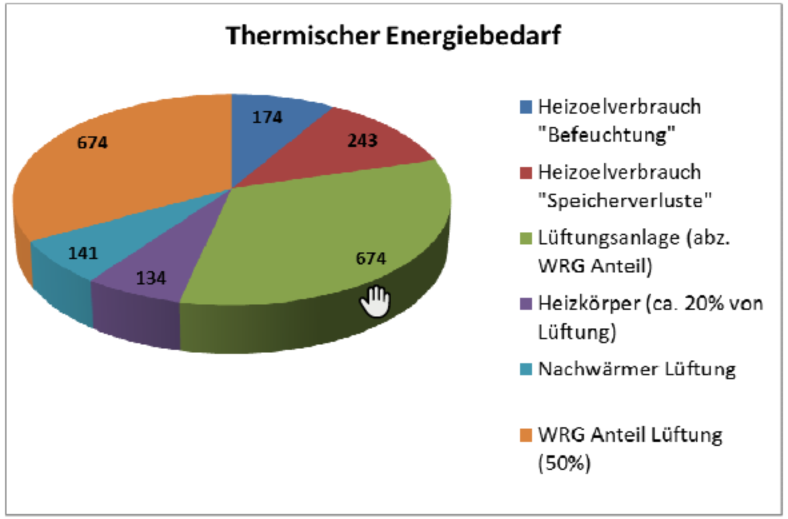
- Daylight-dependent light control
- Better color rendering
- Lifetime factor 5
- Less than 50% of energy consumption compared to former gas discharge lights

Example 6, «Air Conditioning», Optimisation of Cooling System

Starting point: Energy assessment of laboratory «OIPA»

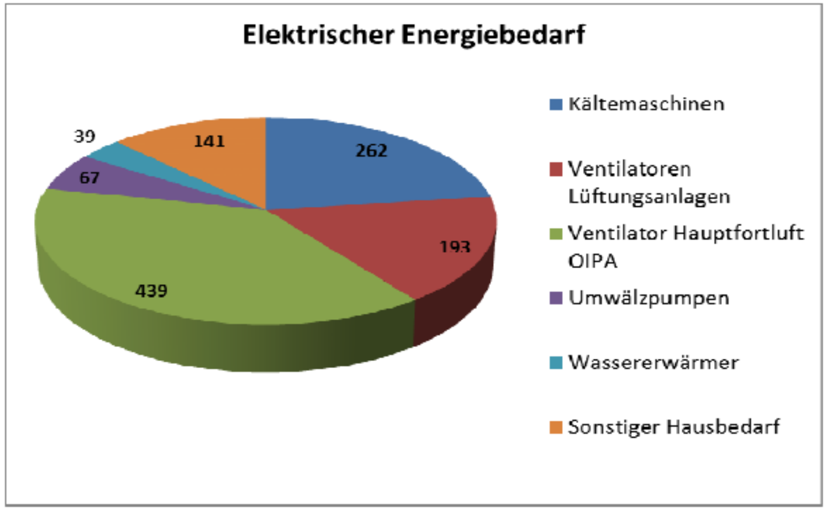
Heat Consumption

Thermischer Energiebedarf		
	MWh/a	%
Heizoelverbrauch "Befeuchtung"	174	9%
Heizoelverbrauch Anteil "Speicherverluste (50%)"	243	12%
Lüftungsanlage (abz. WRG Anteil)	674	33%
Heizkörper (ca. 20% von Lüftung)	134	7%
Nachwärmer Lüftung	141	7%
WRG Anteil Lüftung (50%)	674	33%
Total	2'040	100%



Power Consumption

Elektrischer Energiebedarf		
	MWh/a	%
Kältemaschinen	262	23%
Ventilatoren Lüftungsanlagen	193	17%
Ventilator Hauptfortluft OIPA	439	38%
Umwälzpumpen	67	6%
Wassererwärmer	39	3%
Sonstiger Hausbedarf	141	12%
Total	1'141	100%



- Reduced to 80 MWh (EER 1.3 → ESEER 3.3, Seasonal CW Temp., Freecooling, inefficient HRC eliminated)
- Circulation pumps reduced from 67 to 19MWh

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Example 6, «Air Conditioning», Optimisation of Cooling System

Impressions

Former Ciller consisting of 2 units, year 1984

Assembly of dry cooing unit on the building roof

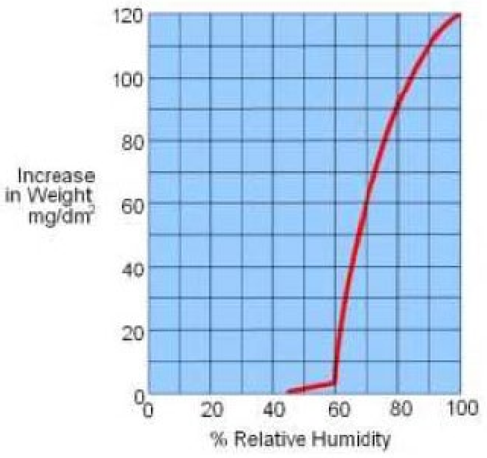
Cooling water distributer including emergency connection

New chillers including buffer tank

Example 7, «Air Conditioning», Humidity Control

Interim storage facility for low-level radioactive waste

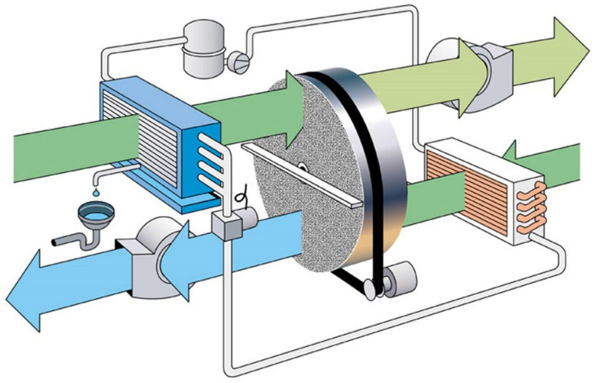
- low air humidity to prevent corrosion
- rel. high air exchange rate



Optimisation:

- Dehumidifying system with combined heat pump- adsorption drying system with a high efficiency and effectivity
- ¼ Consumption compared to basic model, payback time 15 years

Prinzip Wärmepumpen-Adsorptionstrocknung

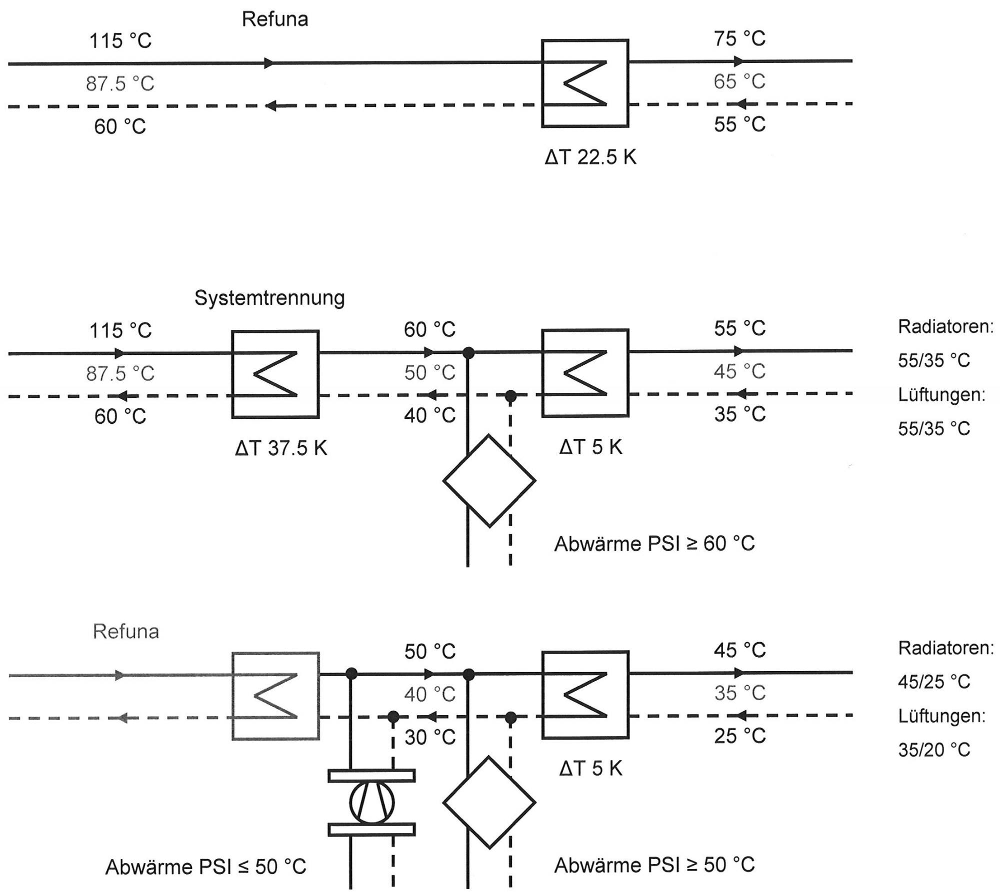


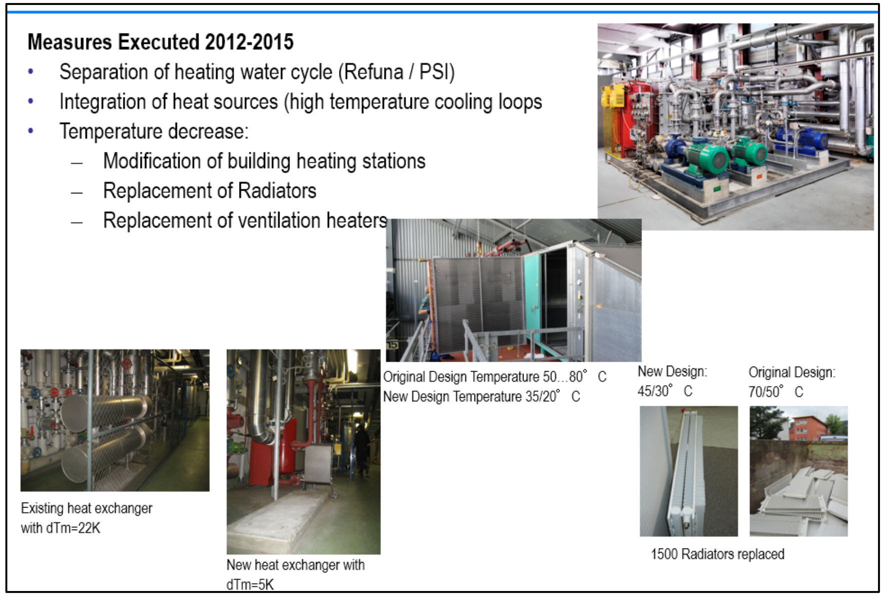
Example 8, «Heating System», Heat Recovery

Original System

Today`s System

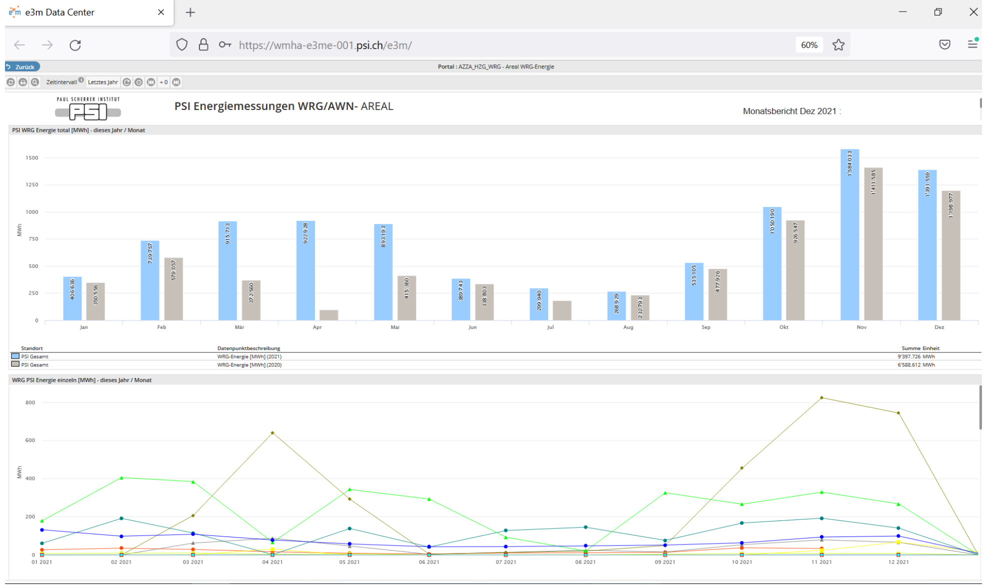
Future System





Presentation ESSRI 2015

Example 8, «Heating System», Heat Recovery



Energy monitoring tool

Total het recovered since 2013	[MWh]	58453
Distric Heat price	[CHF/MWh]	63
Savings since 2013	[CHF]	3'682'535.60
Total Cost	[CHF]	3'785'000.00
break-even point in year		2022
payback time	[year]	9

Successful project since very effective and economic measure!

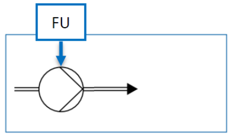
Payback reached: yearly benefit from now: 450kCHF

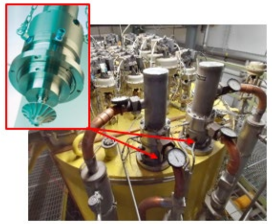
«and much more...»

- Replacement of power supplies HIPA with higher efficiency and stand by mode
- Replacement of transformers
- Renewal of building heating systems (pumps, control systems)
- Energy Assessments and Checks for Laboratories (cleanrooms!)
- Cooling optimisation in central datacenters
- Guidelines for technical building Infrastructure
- Energy monitoring with monthly reports

Outlook of future energy saving measures

Todays identified midterm potentials:





PV plants on PSI roofs	GWh	6
Optimisation Cooling Circuits and Pumps HIPA	GWh	2.5
Contiuous Improovement building technical Infrastructure (10 yeas period)	GWh	1.3
Optimisation Cryogenic Cooling System of Superconducting Test Facility "Sultan"	GWh	2.75
SLS 2.0 Overall Optimisations	GWh	5
Total Power Savings Potential	**GWh**	**17.55**
in % of today`s consumption		12%

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Upgrade SLS 2.0

Upgrade of SLS → SLS 2.0

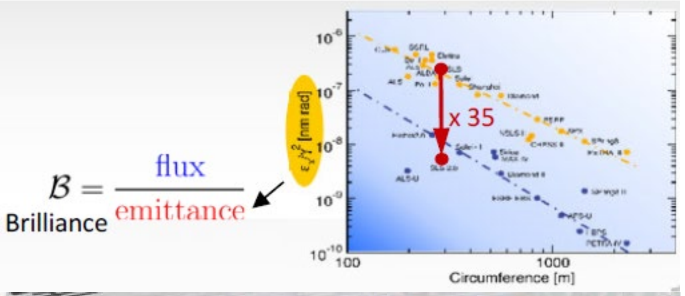
- Brilliance up to 1,000 times higher on certain beamlines.
- Electron energy from 2.4 GeV to 2.7 GeV
- Maximum photon energy from 45 keV to 80 keV
- Beam quality Up to 40 times better than before.
- Inner diameter of the beam pipe decrease from 64 down to 18 millimeters
- Number of magnets increase from 388 to 1`007 (Replacement)

Energy Efficiency Potentials through:

- ”New” technologies & developments
- Optimizing infrastructure concepts
- Adapting to the new boundary conditions,

Project SLS 2.0

An upgrade of strategic importance
for the Paul Scherrer Institute

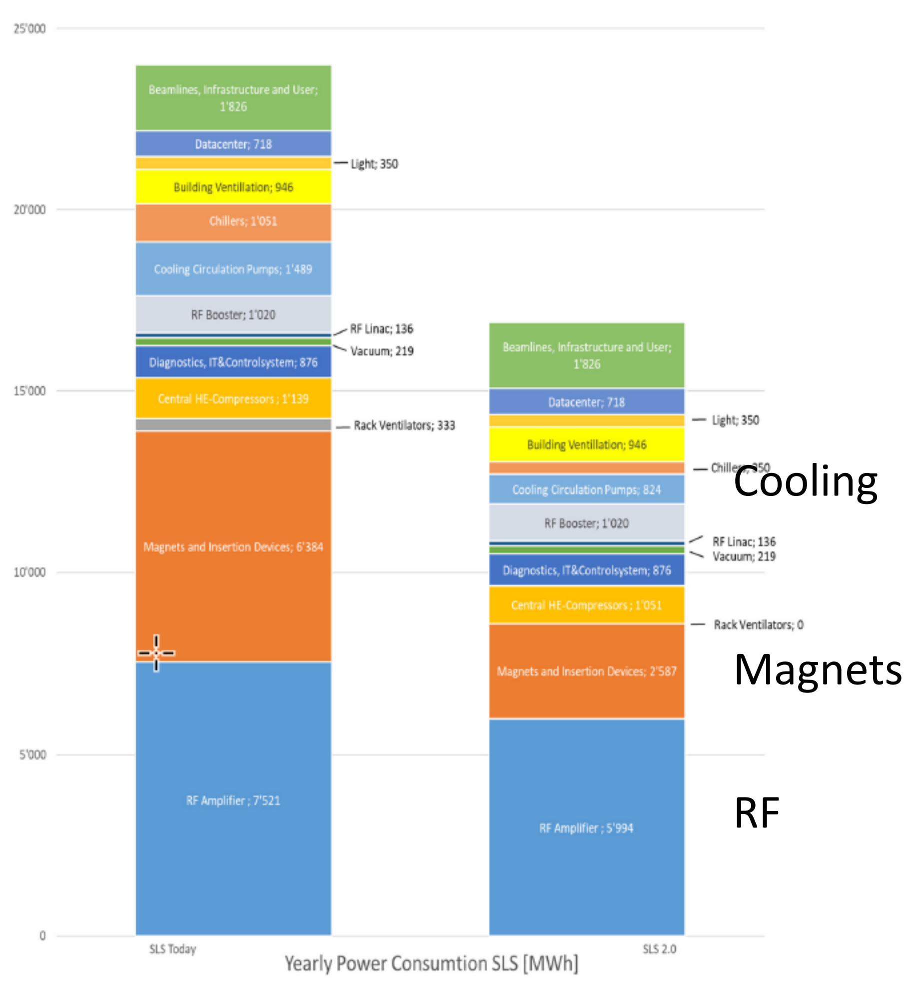


Reduction Potentials SLS 2.0

Energy Optimisation Potentials

Before / After Comparison

Table 1: Left Column, Current Power Consumption theoretical (measured: 22.6GWh); Right Column, Expected Power Consumption 17GWh (Minimum, if all Potentials realised: 25%), exkl. Power Consumption for potential Heat Production for Campus.



Result:

- Increase in output/utility (beam quality approx. factor 40)

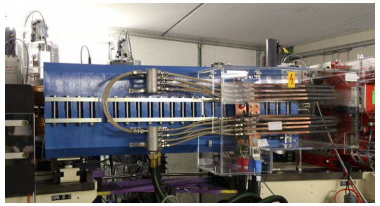
  with a simultaneous

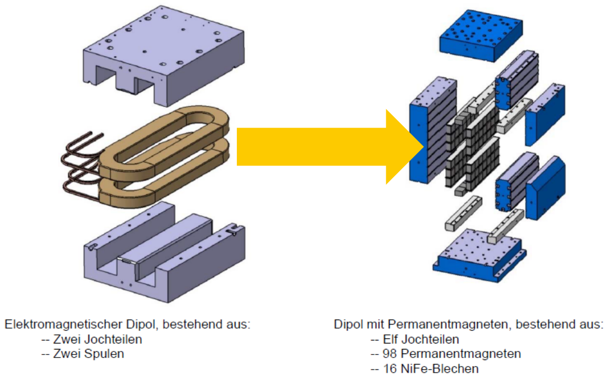
- Reduction of -25% energy consumption

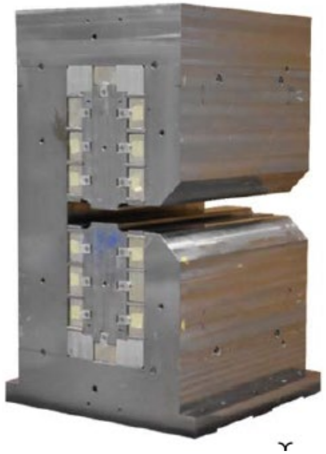
Reduction Potentials SLS 2.0

Main Optimisations (RF Amplifiers and Magnets)

- Use of permanent magnets for the deflection magnets (new development!)







P_{in}=430kW

P_{in}=0kW

- Efficiency increase by replacement of all 4 conventional tube type amplifiers by solid-state amplifiers

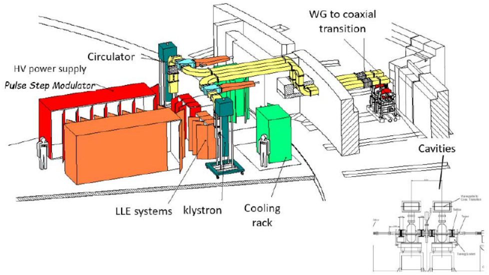


Fig.12: Solid state amplifier station

$\eta = 44\%$

$\eta = 56 \dots 58\%$

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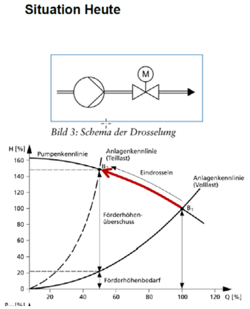
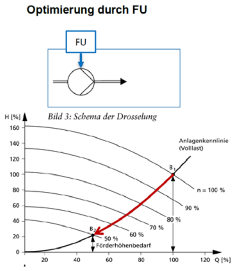
Reduction Potentials SLS 2.0

Main Optimisations (Cooling and PV)

- Optimization of the cooling water production and distribution (VDC, Reduction of Δp, increase ΔT)





- Optional: Use of chillers which can be used as heat pumps in winter (heat recovery, 1.8MW, 2.5 GWh)
- Optional: photovoltaic electricity production on the building roof
  - Due to the limited weight, only light and flexible solar panels can be considered.
  - Roof Area 12`000m2, peak power of about 1 to 1.5 MW, annual energy of about 1 to 1.5 GWh. This would cover about 5 % of the annual energy demand of SLS 2.0.

Wir schaffen Wissen – heute für morgen

Energy Mission PSI

- “Wherever feasible, electricity and heat consumption are reduced to a minimum using long-term concepts and ongoing operational optimisations.”
- https://www.psi.ch/en/about/psi-energy-concept