Energy consumption of cardiology intervention units: a comparative study of operational modes and procedure types

Hannah Staub[a], Christophe A. Wyss[a, b], Oliver Gämperli[a, b], Peter Wenaweser[b], Diana Reser[a, b], Jürg Grünenfelder[a, b], Roberto Corti[a, b], Patric Biaggi[a, b]

a University of Zurich, Zurich, Switzerland; b Heart Clinic Zurich, Zurich, Switzerland

Summary

BACKGROUND: The healthcare sector is a major contributor to climate change, mainly due to greenhouse gas emissions from electricity generation. Radiology imaging devices account for considerable energy consumption, but there is limited knowledge of the energy consumption of cardiac catheterisation units and of specific cardiac interventions.

OBJECTIVES: To quantify energy consumption in kilowatt-hours (kWh) during diagnostic and therapeutic cardiac procedures and to identify potential areas for saving energy.

METHODS: Current transformers measured true power in three cardiac catheterisation units in May and June 2024. The data were matched to system operational modes 'off', 'idle' and 'intervention'. Clinical software provided information about the intervention type, operators and dose-area product.

RESULTS: The total energy consumption was 6647.62 kWh, 76.5% of which was used for non-productive modes (62.8% 'idle' and 13.7% 'off'). Interventions accounted for 23.5% of energy consumption and 9.1% of total time. The median (IQR) energy consumption of 564 performed interventions was 2.20 (2.02) kWh. Coronary interventions with ≥4 stents (4.86 [1.48] kWh) and mitral valve edge-to-edge repair (4.37 [2.59] kWh) used the most, while diagnostic coronary angiograms (0.91 [0.74] kWh) used the least energy from first to last scanning action. Energy consumption correlated significantly with intervention time ($r = 0.98$, $p < 0.001$) and dose-area product ($r = 0.62$, $p < 0.001$).

CONCLUSION: Non-productive operational modes accounted for more than ¾ of overall energy consumption. Reducing 'idle' energy consumption appears to have the largest energy-saving potential.

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Prof. Dr. med. Patric Biaggi
Heart Clinic Hirslanden
Witellikerstrasse 40
CH-8032 Zurich
patric.biaggi [at]hirslanden.ch

Introduction

Human-induced greenhouse gas emissions have caused an unprecedented global temperature rise, reaching mean global temperatures of 1.5 °C above pre-industrial levels in recent years [1]. The resulting climate change has serious consequences for humans and the environment [1] and jeopardises healthcare systems on a global scale [2].

The combustion of fossil fuels to generate electricity and heat accounts for 68% of total greenhouse gas emissions, making it the largest contributor to climate change [3]. Reducing electricity consumption, increasing energy efficiency and transitioning to renewable energy sources are therefore sustainable approaches to inhibit the progression of global warming [4].

The healthcare sector itself accounts for 4.4% of net global greenhouse gas emissions, over half of which result from electricity production [2]. Radiology imaging devices are associated with high energy consumption and cause up to 10% of total emissions in healthcare [5, 6]. Computed tomography and magnetic resonance imaging devices alone account for up to 12.5% of total hospital energy consumption [7].

Interventional cardiology uses fluoroscopy with potentially high energy consumption. The environmental impact of catheter units has been studied in previous research [8, 9]. However, quantitative data on electricity demand is limited, especially for specific cardiac interventions. This study aims to quantify energy consumption during cardiac catheter procedures and to identify potential areas for energy-saving measures.

Methods

The study was performed by Heart Clinic Zurich at Hirslanden hospital in Zurich, Switzerland, in cooperation with local electricians as well as InterSys AG (InterSys AG, Zuchwil, Switzerland). InterSys AG provided both the technical equipment and the corresponding online software. The study was granted a full waiver of informed consent by the ethics committee of the canton of Zurich KEK ZH, Switzerland (BASEC-Nr. Req-2023-01484).

Study setting and design

Hirslanden hospital is a tertiary care medical centre with advanced imaging technology, with three catheter units performing cardiology interventions. For two months, installed power meters logged energy measurements in real time for all three units, which were then matched to patient records for further analysis. A prospective comparative study was performed to compare energy consumption of operational modes (‘off’, ‘idle’, ‘intervention’), different catheter units and procedure types. The primary objective was to identify operational modes and times where energy efficiency could be optimised without impairing patient safety or procedure quality. As a secondary objective, we aimed to provide comparative data on the energy consumption of individual interventional cardiology procedures. The months May and June were selected based on calculations of the caseload of previous years. Multiplying the measured cases by a factor of six matched the annual caseload (error of ±5%).

Current transformers (Shelly Pro 3EM-400; ID-nr. 3800235268117; Shelly Europe Ltd, Sofia, Bulgaria) were installed in three intervention rooms measuring the electricity consumed by the representative fluoroscopy system. The ‘system’ consisted of all electricity used for the C-arm itself, the intervention table, the large intervention monitor, the power injector for contrast agent as well as computers and screens in the control room used for intervention guidance as well as pre- and postprocessing of images and clinical data. Due to technical limitations, we were not able to separately measure electricity used for light, air conditioning, additional equipment such as ultrasound machines or ventilators, or independent electricity plugs. The intervention rooms were each equipped with catheterisation units by Philips (Philips Healthcare, Netherlands): monoplane Azurion 7M12C in catheter laboratory (CL) 1, biplane Azurion 7B12 in CL2, monoplane Allura Clarity FD20 ORT in the hybrid operating room. Monoplane imaging units are equipped with a single C-arm X-ray, making them more space-efficient and suitable for general cardiovascular procedures. Repositioning the C-arm may lead to longer procedure duration and higher contrast use. Biplane scanning units use dual C-arms, allowing for simultaneous multi-angle imaging, thus using less contrast and producing 3-dimensional images. They require more infrastructure and space, but may be suitable for more complex procedures [10]. The monoplane scanning unit in the hybrid operating room was used to treat all vascular and structural heart diseases, as well as a few non-cardiovascular interventions without any scanning actions.

The current transformers measured current [A = ampere], voltage [V = volt], true [W = watt] and apparent [VA = volt-ampere] power at 1-second intervals for 61 consecutive days (1 May to 30 June 2024). Only true power data are reported in this study. The mean power consumption was measured in watts [W]. The energy consumption per second was calculated as kilowatt-hours [kWh] (kWh = W / [3.6×10^6]). The data were stored in large Excel files and displayed as a continuous bar graph in the software program Ivaluation (non-licenced, developed by InterSys AG, using telemetry data transmitted via MQTT-Broker to an IoT platform [ThingsBoard, ThingsBoard Inc.]), which allowed real-time comparison of measured data and procedures performed.

Definition of operational modes

We defined operational modes ‘off’, ‘idle’ and ‘intervention’. The ‘off’ mode was defined as continuous power with the systems turned off. The ‘idle’ mode was defined as continuous power at baseline level with the catheter unit turned on. During ‘idle’, the unit was fully functional but no intervention was being performed. The periods from patient entry into the lab to the beginning of scanning actions and from the last scanning actions to patient exit from the lab were classified as ‘idle’.

Failed procedures were classified as 'intervention'. Cut-off values for 'off' and 'idle' modes were identified individually per intervention room using Ivaluation. The start of the 'intervention' mode was defined as power exceeding baseline power for the first time in at least 10 minutes and followed by comparable peaks. The end of the 'intervention' mode was defined as the absence of power peaks for at least 10 minutes. Ten minutes was considered the minimal change time between interventions. As the exact times of patient entry/exit into/from the operating rooms were not recorded consistently in patient charts, each intervention was defined as the period between the first and last scanning actions. As the preparation and deinstallation of the patients did not increase energy consumption, they were not considered part of intervention energy.

Interventions, dose-area product, operators, costs

The dose-area product (DAP) is calculated as the product of dose and beam area (mGy × cm^2), an indication of the radiation dose received by a patient [11]. Performed intervention types, the corresponding DAP and operators were identified using the clinic's software (Krankenhausinformationssystem M-KIS, Meierhofer, Germany; IntelliSpace Cardiovascular, Philips Healthcare). We included all procedures logged in the cardiovascular image management program in this study. Power peaks without corresponding entries in the program were reclassified from 'intervention' to 'idle' and retrospectively identified as function testing periods. Information about pricing of energy consumption for the time mentioned was provided by the clinic management. The cost calculation was based on hospital reference data (1 kWh equals 0.30 CHF), and the Swiss energy mix was used to calculate CO_2 emissions per kWh energy (112 g CO_2 per kWh) [12].

Statistical analysis

We analysed two datasets. The first consisted of daily records, including number of interventions, operational mode duration, energy consumption and power per laboratory. No missing values were detected for operational mode duration, energy consumption, power per laboratory or number of interventions. Thus, all daily data were analysed. The Shapiro-Wilk test indicated non-normal distribution of power consumption within each laboratory and operational mode. Therefore, medians and interquartile ranges (IQR) are reported.

The second dataset comprised individual procedures with their associated type, duration, energy consumption, DAP, operator and laboratory. Procedures lacking information on intervention type (e.g. failed procedures) or without any scanning actions were excluded from type-specific analysis. Outliers among successful interventions were retained. For all other variables, missing data were minimal and not imputed. The Shapiro-Wilk test revealed non-normality. Consequently, statistics are reported as medians and IQRs. For every intervention type, Spearman's rank correlation was applied to assess the associations between energy consumption and the variables dose-area product (DAP) and duration. A Kruskal-Wallis test was used for specific intervention types to assess whether energy consumption differed between monoplane CL1 and biplane CL2. We applied the one-sample Wilcoxon signed-rank test to evaluate whether energy consumption values for individual operators differed from the overall operator median. The sample size precluded comparison of operators for individual intervention types. Energy consumption differences between intervention types were not assessed, as clinical indication and not energy efficiency determines which procedure is applied.

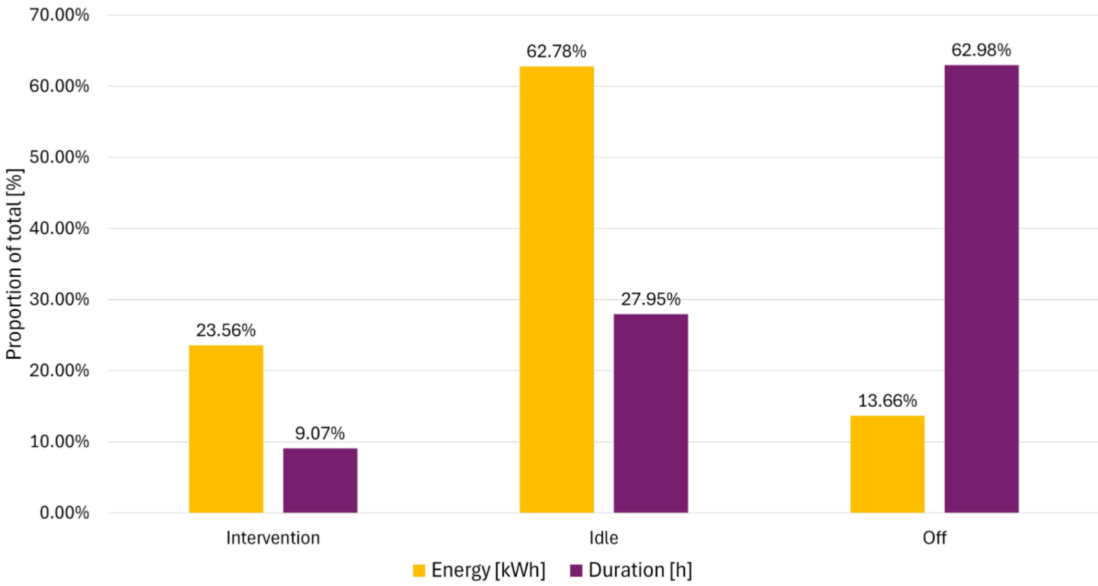
We defined a p-value of <0.05 as statistically significant. Statistical analysis was performed using RStudio 2024.09.0+375 and Microsoft Excel version 2501.

Results

Overall energy consumption

During the two months of data collection, the energy consumption in the three intervention rooms was 6647.62 kWh (table 1). Most of the energy was used for the non-productive mode 'idle' (62.8%), while interventions contributed to 23.6% of total energy consumption (figure 1). 37.1% of time was spent with the catheter unit ready for scanning action ('idle' or 'intervention' mode), equivalent to 8.9 hours per day. The least time was spent during interventions (9.1% or 2.2 hours, figure 1).

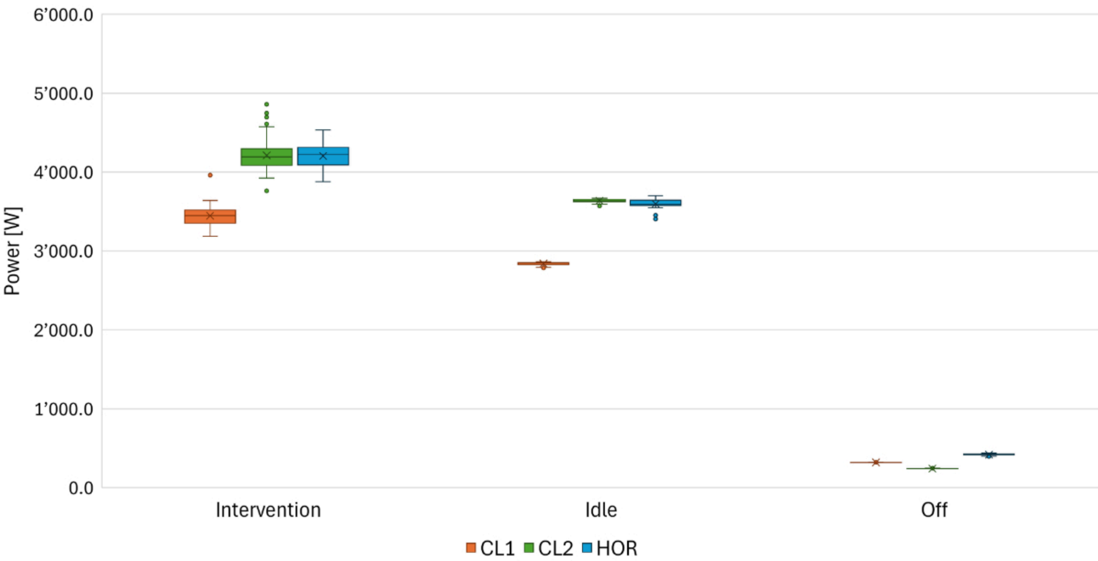
Figure 1: Total proportions of energy [kWh] and duration [h]. Total proportion of energy consumption (kWh) and operating time (h) for 'intervention', 'idle' and 'off' modes in catheter laboratories. The majority of energy is consumed during the 'idle' mode.



Energy per intervention room

For monoplane CL1, the median power output was lower in 'intervention' and 'idle' compared to biplane CL2 and monoplane hybrid operating room (figure 2). Switching from 'off' to 'idle' increased power output by 2500–3400 W (an increase of 860–1501%), depending on the catheter unit. The power needed for image generation during interventions further increased median power consumption by about 600 W in all three systems (17–21% increase compared to 'idle' mode).

Figure 2: Median power [W] by operational mode. Boxes represent interquartile range (IQR), depicting central 50% of data points between first and third quartiles. The horizontal line in each box marks the median. Whiskers extend to the most extreme data points with 1.5 times the IQR and dots indicating outliers. Median power (IQR) by operational mode (intervention / idle / off) was 3448.09 W (163.79) / 2844.32 W (23.56) / 318.73 W (1.10) for catheter laboratory 1 (CL1); 4190.79 W (168.80) / 3635.76 W (28.27) / 240.78 W (2.28) for catheter laboratory 2 (CL2); and 4225.74 W (215.20) / 3593.95 W (59.46) / 418.14 W (1.07) for the hybrid operating room (HOR).

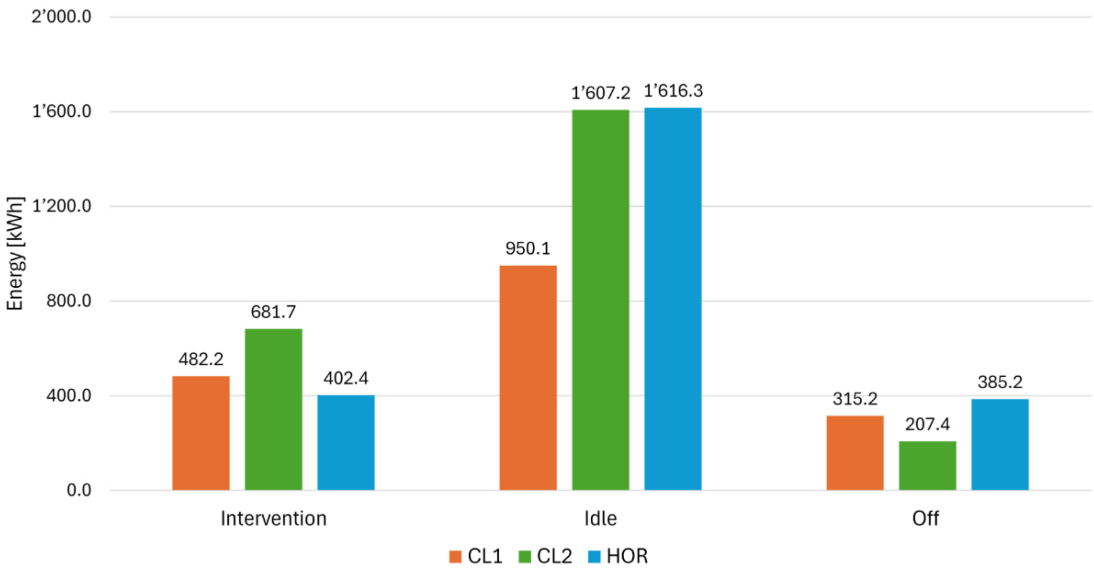


Biplane CL2 had the highest total energy consumption (37.6% of combined total energy, table 1) and the highest energy consumption for interventions (figure 3), while also having the longest active state ('idle' and 'intervention' time). In all three rooms, the largest amount of energy was consumed during the 'idle' mode (figure 3).

Table 1: Baseline data.

Total number of interventions, n	564
... Coronary, n (%)	449 (79.61%)
... Structural heart disease, n (%)	90 (15.96%)
... Other, n (%)	25 (4.43%)
Total number of operators, n	21
... Operators with >10 interventions, n (%)	11 (52.38%)
Days analysed, n	183
... Days with interventions, n (%)	133 (72.68%)
... Days without interventions, n (%)	50 (27.32%)
Total energy consumed in kWh	6647.62
Energy per operating room in kWh (%)	
... CL1	1747.38 (26.29%)
... CL2	2496.42 (37.55%)
... Hybrid operating room	2403.96 (36.16%)
Energy per operational mode in kWh (%)	
... 'Intervention'	1566.30 (23.56%)
... 'Idle'	4173.54 (62.78%)
... 'Off'	907.78 (13.66%)
Median energy per intervention in kWh (IQR)	2.20 (2.02)
Total time in h	4392
Total intervention time in h (% total time)	398.33 (9.07%)
... CL1	140.41 (9.59%)
... CL2	161.97 (11.06%)
... Hybrid operating room	95.96 (6.55%)
Median time per intervention in h (IQR)	0.57 (0.48)

Figure 3: Total energy consumption [kWh] in two months. The total energy consumption (EC) for two months was highest in catheter laboratory (CL) 2, followed by the hybrid operating room (HOR) and CL1. CL2 had the highest energy consumption during the energy-intense 'intervention' mode and the lowest energy consumption during the 'off' mode.



Energy per intervention

Of 183 days, procedures were carried out on 133 days. Of the 50 days without interventions using a scanning unit (public holidays, weekends), 24 occurred in the hybrid operating room, which is primarily used for elective structural coronary and vascular interventions and therefore never used for emergencies. During the 61 days analysed in three operating rooms, 564 interventions were conducted, with the majority (79.6%) being coronary procedures, followed by procedures for structural heart disease (16.0%, table 1). For each intervention type, median DAP, duration and energy consumption from first to last scanning action per intervention type are reported in table 2.

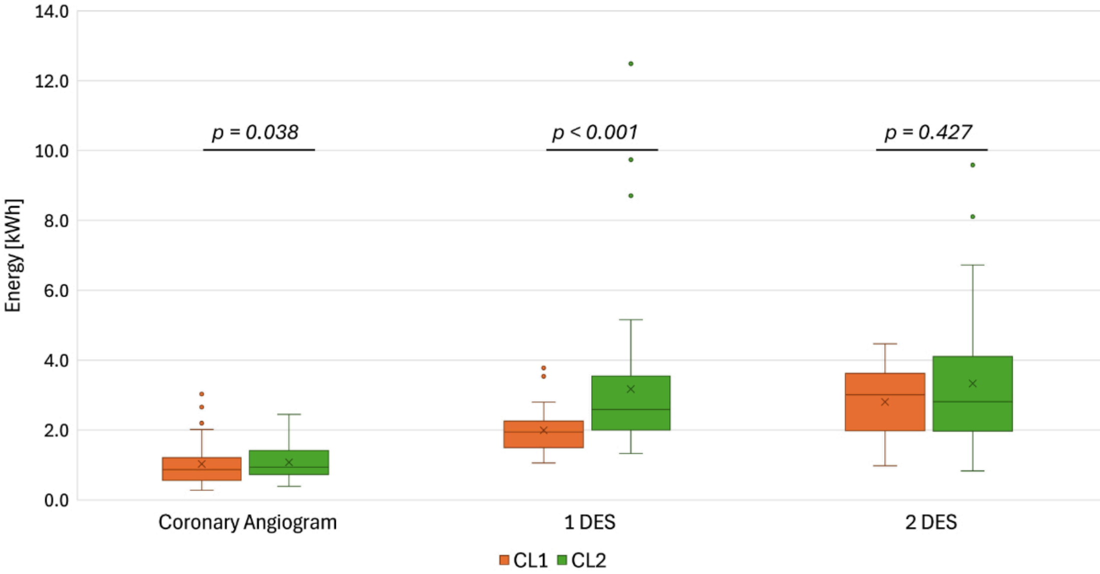
Table 2: Median duration, dose-area product (DAP) per intervention type; Spearman's rank correlation coefficients between energy and duration/DAP, and stratified by intervention type.

Procedure type	n	Duration [h]		Energy [kWh]		DAP [mGy × cm]		Spearman's rank correlationEnergy - Duration		Spearman's rank correlationEnergy - DAP	
		Median	IQR	Median	IQR	Median	IQR	Correlation coefficient	p-value	Correlation coefficient	p-value
Diagnostic coronary angiogram	144	0.24	0.20	0.91	0.74	14.08	12.40	0.975	<0.001	0.547	<0.001
Combined left and right heart catheterisation	44	0.43	0.16	1.60	0.68	17.01	19.71	0.921	<0.001	0.417	0.005
PCI with 1 DES	73	0.59	0.31	2.25	1.02	27.61	20.84	0.939	<0.001	0.333	0.004
PCI with 2 DES	63	0.74	0.53	2.97	2.01	34.64	48.58	0.947	<0.001	0.434	<0.001
PCI with 3 DES	24	0.75	0.34	2.79	1.06	33.41	26.94	0.943	<0.001	0.234	0.271
PCI with ≥4 DES	25	1.29	0.57	4.86	1.48	42.37	35.31	0.898	<0.001	0.608	0.002
PTCA with drug-eluting balloon DEB	19	0.67	0.30	2.53	0.96	34.16	26.50	0.960	<0.001	0.756	<0.001
PCI with 1 DES and ≥1 DEB	28	0.96	0.58	3.63	2.35	48.41	63.03	0.961	<0.001	0.472	0.011
PCI with 2 DES and ≥1 DEB	18	0.82	0.55	3.35	2.15	31.61	42.69	0.861	<0.001	0.309	0.212
PCI with 3 DES and ≥1 DEB	5	0.86	0.29	3.14	0.98	36.92	13.47	1.000	0.017	0.300	0.683
Transcatheter arterial valve implantation (TAVI)	54	0.65	0.25	2.86	1.19	31.97	53.83	0.992	<0.001	0.557	<0.001
Mitral transcatheter edge-to-edge repair	18	1.01	0.62	4.37	2.59	22.56	35.60	0.995	<0.001	0.614	0.008
Tricuspid transcatheter edge-to-edge repair	8	0.97	0.67	3.95	2.83	33.33	24.53	1.000	<0.001	0.833	0.015
Percutaneous patent foramen ovale closure	8	0.41	0.15	1.41	0.62	7.07	5.25	0.994	<0.001	0.595	0.132
Percutaneous left atrial appendage closure	2	0.74	0.41	2.89	1.51	9.84	1.75	NA	NA	NA	NA
Pacemaker implantation	6	0.48	0.17	1.89	0.68	14.79	4.29	1.000	0.003	0.200	0.783
Non-coronary mixed interventions[c]	8	0.51	0.99	1.84	3.32	14.98	44.20	0.976	<0.001	0.690	0.069
EVAR; CERAB	17	0.83	0.72	3.36	2.71	290.09	164.85	0.987	<0.001	0.397	0.116
Total	564	0.57	0.48	2.20	2.02	25.48	36.57	0.983	<0.001	0.618	<0.001

[a] Values are Spearman's correlation coefficients between duration and energy, and between dose-area product and energy, and stratified by intervention type.
[b] p-values are exploratory.
[c] Percutaneous transhepatic cholangiography and drainage (PTCD), peripheral arterial revascularisation, pericardiocentesis, cardiac resynchronisation therapy with pacemaker (CRT-P), femoral popliteal bypass.
CERAB: covered endovascular repair of aortic bifurcation; DEB: drug-eluting balloon; DES: drug-eluting stent; EVAR: endovascular aneurysm repair; PCI: percutaneous coronary intervention; PTCA: percutaneous transluminal coronary angioplasty

The lowest median energy consumption was achieved during diagnostic angiograms at 0.91 kWh (IQR: 0.74), also accounting for the shortest median intervention time at 0.24 h (IQR: 0.20). Coronary interventions with 4 or more stents had the highest energy consumption (4.86 kWh, IQR: 1.48), also being the longest interventions (1.29 h, IQR: 0.57). Overall, energy consumption correlated significantly with both the duration and the DAP ($r = 0.98$ and $r = 0.62$, respectively, both $p < 0.001$). Energy consumption also depended on the intervention room, being lower in monoplane CL1 compared to biplane CL2 for two of the three most performed procedures (figure 4).

Figure 4: Median Energy Consumption [kWh] per intervention in CL1, CL2. Boxes represent interquartile range (IQR), depicting central 50% of data points between first and third quartiles. The horizontal line in each box marks the median. Whiskers extend to the most extreme data points with 1.5 times the IQR and dots indicate outliers. Biplane catheter laboratory (CL) 2 exhibits higher median energy consumption for 1 drug-eluting stent (DES) (p <0.001) and for coronary angiogram (p = 0.038) when compared to monoplane CL1. Performing procedures in CL1 reduces energy consumption.



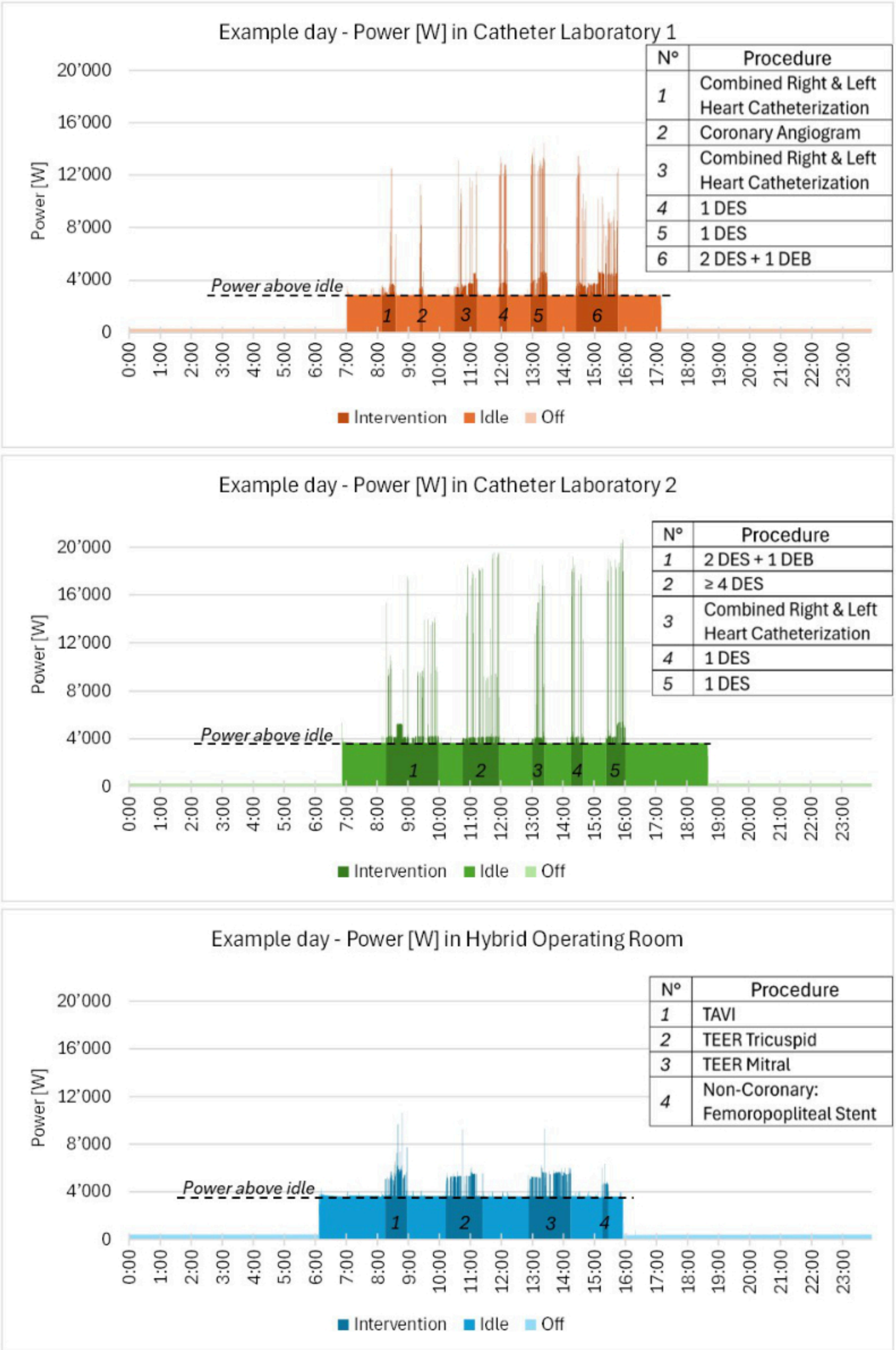
Energy per operator

11 of the 21 medical professionals performing interventions conducted more than 10 interventions (table 2). For these operators, the total median energy consumption was 2.19 kWh. The median energy consumption of four operators differed significantly from this overall value: 1.66 kWh (p = 0.005), 2.99 kWh (p <0.001), 2.98 kWh (p = 0.003) and 2.59 kWh (p = 0.003). It was not possible to stratify the median energy consumption per operator by intervention type, due to limited sample sizes in several combinations of operator and intervention type. Operators conducted a heterogeneous mix of shorter, less energy-intense and longer, more energy-intense interventions, which may partially explain the observed differences in median energy consumption between operators.

Example days

Typical procedure days are illustrated for each catheterisation unit in figure 5. Between 4 to 6 interventions were performed on the example days. The peak power output during scanning reached values greater than 20,000 W in CL2. However, the energy used for actual scanning during an intervention (also called ‘net imaging’ energy consumption), when regarded as additional to baseline ‘idle’ energy, contributed only between 6.04% to 25.04% to the total energy consumption during an intervention.

Figure 5: Power [W] on example days. Manually selected 24-hour period of power output (second-interval measurements) display a typical distribution of operational modes. Interventions include implantation of drug-eluting stents (DES) and drug-eluting balloons (DEB), transcatheter arterial valve implantation (TAVI) and transcatheter edge-to-edge repair (TEER). During interventions, only 6.04–25.04% of energy consumption (EC) was due to scanning action (peaks exceeding 'idle' mode energy consumption). Lowering baseline power consumption will decrease energy consumption even during interventions.



Annual energy consumption, cost and CO2 emissions

During the 2-month measurement period, the type and number of interventions and the utilisation of the catheter units were comparable to previous years. Accordingly, the total annual energy consumption was estimated at 39,885.72 kWh, corresponding to CHF 12,037.51 and equivalent to 4.47 tons of CO_2 emissions annually.

Discussion

This study reports the energy consumption in three different cardiology intervention rooms for various operational modes, energy consumption and duration of performed cardiology interventions and an estimation of CO_2 emissions. While there have been studies on the energy consumption of operational modes of catheter units [9], this study offers a novel detailed analysis of 564 diagnostic and therapeutic cardiac procedures, sorting them into 18 groups to compare energy consumption and duration and thus the environmental impact of each group. The energy consumption showed strong correlation with both the duration and the dose-area product of interventions.

‘Idle’ mode, a waste of energy

The largest part of total energy was used during the unproductive ‘idle’ mode (62.8% of total energy consumption). Furthermore, during the ‘intervention’ mode only 6.04–25.04% of energy consumption was due to scanning actions, represented by peaks higher than the mean ‘idle’ power. Thus, an estimated 80% of energy is consumed for non-productive baseline functions during ‘idle’ and ‘intervention’ modes combined. The literature on sustainability in radiology departments confirms these findings, as 40–91% of energy is consumed during non-productive operational modes [9]. Strategies to reduce energy consumption during the ‘idle’ mode and for baseline functions could yield significant energy savings [5, 9]. Even though the ‘off’ mode was the longest of any operational modes, it also contributed the lowest energy consumption, therefore not offering room to increase energy efficiency.

Strategies for saving energy

There is growing concern about the impact of the healthcare system on climate change [13]. Implementing operational and technological energy-saving strategies to reduce energy consumption will improve energy efficiency and thus reduce greenhouse gas emissions [14]. However, environmental considerations should never influence clinical decision-making or compromise quality of patient care.

Firstly, ‘idle’ mode duration can be reduced by switching catheter units on only shortly before interventions and by reducing prolonged turnover intervals, either by performing more interventions (thus increasing energy efficiency per patient) or scheduling them closer together. In addition, switching off scanning units immediately after the intervention is completed would further reduce 'idle' mode duration.

For approaches that reduce the ‘idle’ mode by switching the unit off between patients, it is essential to separate the power supply for scanning units from other devices in the operating room, as monitoring screens and computers can currently not be operated when the scanning unit is turned off. Switching the catheter units on/off increases/reduces power consumption linearly without any power peaks, thus not increasing energy consumption, takes less than five minutes and does not wear internal components [9].

Secondly, improved technology could lower energy consumption with no impact on workflow by lowering power consumption of baseline functions especially during ‘idle’ and ‘intervention’ modes. However, developing more energy-efficient scanning units is complex and replacement of currently fully functioning systems would be neither cost-efficient nor sustainable.

Thirdly, future software may introduce an automated energy-saving mode as an alternative to the ‘idle’ mode. In such a mode, the fluoroscopy system would not be ready to scan but recorded scans would be able to be analysed. Automated energy-saving modes have been implemented in the automobile industry, leading to considerable fuel savings (26.4%) [15]. Alternatively, further technical development may allow independent operation of energy-intense parts of the scanning system (C-arm, patient table, large intervention monitor).

Such strategies have already proven to be effective. Decreasing power consumption during the ‘idle’ mode and manually turning off devices lead to significant energy and cost savings, according to studies performed in radiology departments [5, 9]. Further research on the energy-saving potential for devices of different vendors and future products is warranted [16].

The impact of intervention type and operator

This study offers a comparison of three different catheterisation imaging systems and a detailed analysis of 564 interventions, their duration and energy consumption. The interventions varied significantly in duration and energy consumption, with more-complex procedures taking longer and using more energy. The median energy consumption for a diagnostic coronary angiogram was 0.9 kWh, similar to a coronary computed tomography (1.3 kWh) but significantly lower than a cardiac MRI (around 17 kWh) [7]. Although the median energy consumption of four operators differed significantly from the total median, efforts to save energy at the individual operator level risk procedure quality and do not harbour the same potential for energy savings as measures to reduce idle energy consumption. Quantitative data on the ecological footprint caused by energy consumption of cardiology interventions allows more precise calculation of greenhouse gas emissions of scope 3 [17].

The bigger picture

Healthcare accounts for approximately 4.4% of global emissions [2], with medical imaging alone contributing up to 10% [6]. Electricity supply and power generation causes 53% of the healthcare sector's carbon footprint [2]. Reducing energy consumption alongside decarbonisation of electricity generation is therefore essential. The annual energy consumption of the three catheter intervention rooms was projected to be around 40 MWh, which is comparable to the annual energy consumption of eight 4-person households and accounts for 0.47% of the hospital's total energy consumption of 8.5 million kWh in 2022, representing a small but not negligible share of the hospital's overall energy consumption [18, 19]. For one year, the energy cost amounted to more than CHF 12,000 and the carbon footprint was calculated as 4.5 tons of CO_2, comparable to the emissions of a car journey around the circumference of the earth [20]. When including the clinic's two electrophysiology labs, the neuro suite, all computed tomography and MRI scanners, the energy consumption is estimated at 10% of the hospital energy consumption. Implementing technical and operational energy-saving strategies that reduce 'idle' energy could lead to a substantial reduction of energy consumption, running costs and carbon footprint of cardiac interventions.

Study limitations

This study is limited by the collection of data being restricted to two months and three different catheterisation rooms not of the latest generation. Data per intervention are limited, may not be generalised to other hospitals or compared to newer systems and those of different vendors. Furthermore, the intervention volume may be higher at other centres, thus having lower turnover time and 'idle' energy consumption.

The definition of an intervention is limited to a period with peaks of power being above the idle value. Hence, an intervention begins by the first scanning action and ends with the last scan. Any energy used before the first scan or after the last scan was not attributed to the intervention itself.

The measured energy consumption only includes energy that is part of the fluoroscopy system. All other energy used (air conditioning, light, power plugs, running anaesthesia and ultrasound equipment) was not measured. The environmental impact of cardiac catheter procedures beyond energy was not assessed. The lack of these data leads to an underestimation of the carbon footprint per intervention and total energy consumption.

Lastly, the CO_2 emissions per kWh remain hypothetical, as the electricity in each country and hospital depends on the local energy mix (combination of the country's energy production, export and import). Switzerland produces most of its electricity from hydropower and other renewable sources. However, seasonally imported electricity from neighbouring countries is partly generated from fossil fuels with higher CO_2 emissions [12].

Conclusion

This study concludes that energy consumption in three different cardiology intervention suites is by far highest for the 'idle' mode, harbouring a large energy-saving potential. Energy used for interventions represents less than 25% of total consumption and correlates with DAP and intervention duration. Therefore, measures to reduce energy consumption should be of a technical and operational nature, mainly by reducing the energy consumption and duration of the 'idle' mode. Further research into the effect of these measures is needed.

Data availability statement

Deidentified study data are not openly available at this point in time due to the large dataset size and associated logistical constraints. However, the authors are open to sharing relevant portions of the raw data on a case-by-case basis. Data may be made available for non-commercial, academic research purposes, particularly for studies aiming to improve the energy efficiency of fluoroscopy systems. Data-sharing requests will be individually evaluated by the first and senior authors of this article and, if approved, data will be exchanged directly with the requesting researchers.

Financial disclosure

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Potential competing interests

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