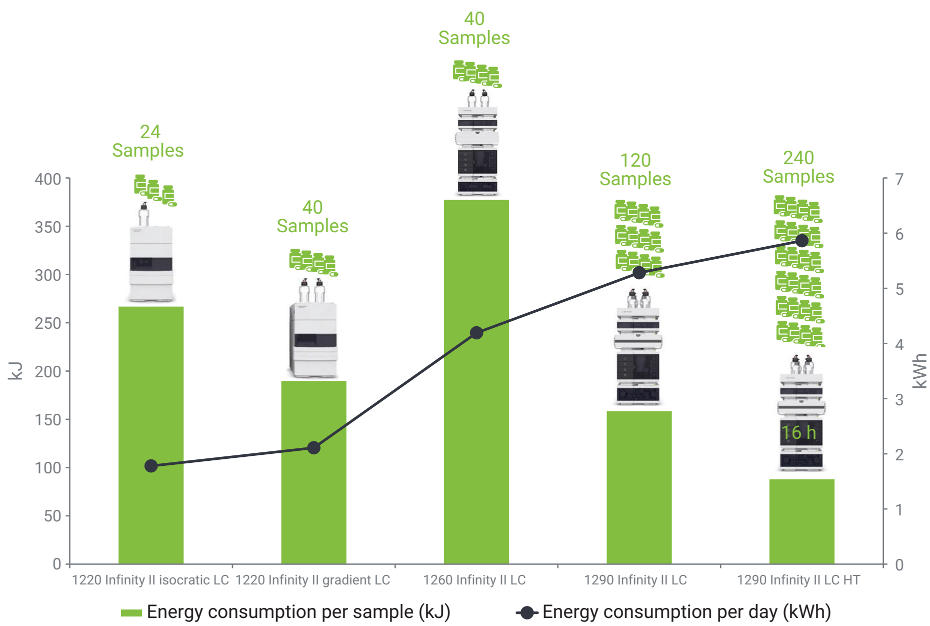
Technical Overview

Do You Know the Environmental Impact of Your HPLC?

Energy consumption of four InfinityLab LC systems during routine operation



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Abstract

Being environmentally sustainable is a goal many companies have adopted into their guidelines. Laboratories, as resource-intensive spaces, are a hotspot where actions towards higher sustainability can make a difference. To inform about and assess the environmental impact of laboratory products, the nonprofit organization My Green Lab has launched the ACT label, which considers, among other factors, the energy consumption of electric lab products. This technical overview presents details on the energy consumption of four ACT-labeled Agilent LC systems and their energy consumption per sample. To assess the environmental impact of a purchase decision and meet company sustainability goals, it is important for scientists to know the overall energy consumption of an LC, but more importantly the energy consumption per measured sample.

Introduction

Laboratories are one of the most resource-intensive workplaces, which is why virtually every company maintaining research laboratories has defined environmental and sustainability guidelines. Their goals, for example, are to reduce emissions over the next five years to be carbon neutral[1] or to even have zero emissions.[2] Acting environmentally sustainable is not limited to reducing carbon dioxide emissions. Laboratories require water and energy to operate equipment, and many consumables are made of new plastic instead of reusable or recycled materials. To assess the environmental impact of producing, using, maintaining, and disposing of laboratory products, the nonprofit organization My Green Lab has created the ACT label (Figure 1). Being an acronym for accountability, consistency, and transparency, the ACT label can be considered an eco-nutrition label for lab equipment, consumables, and chemicals.

Since its founding in 2013, My Green Lab has audited and certified more than 400 laboratories,[3] including renowned institutions and companies such as the Massachusetts Institute of Technology (MIT), the University of California, and AstraZeneca. A growing number of manufacturers of laboratory equipment, consumables, or chemicals have registered over 230 products under the ACT label,[4] which can be reviewed in the ACT database at act.mygreenlab.org.

To issue an ACT label, My Green Lab reviews and rates—by an independent third-party organization (SMS Collaborative, Wilmington, DE)—the following criteria, among others:

- Renewable energy use during production
- Content of product and packaging
- Energy consumption during use
- Product lifetime
- Recycling of product and packaging after end of life

Agilent had the 1220 Infinity II, the 1260 Infinity II, and the 1290 Infinity II LC instrument families audited and received the according ACT labels for the United States, the United Kingdom, and the European Union. Knowledge about the environmental impact of manufacturing, using, and disposing of a product helps the customer make a more environmentally informed decision during purchase. In certified labs, it might even be necessary to present an ACT or a similar label to meet the lab's sustainability goals.

As complementary information to the ACT database, this technical overview presents details on the energy consumption under analytical conditions typical for the different instrument families. Instead of optimizing the energy consumption to the lowest possible value, the goal was to use methods and analytical conditions that represent a realistic use case. A commercially available sample was separated on each system using typical instrument parameters and analysis run times.

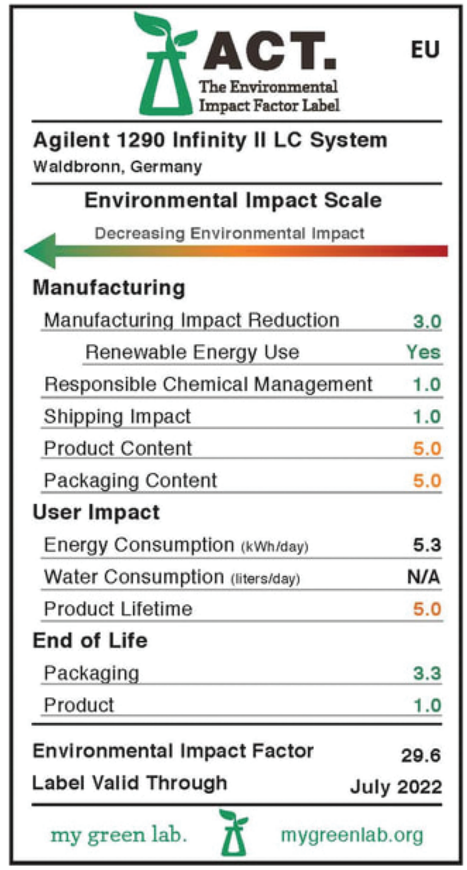


Figure 1. ACT label for an Agilent 1290 Infinity II LC System, valid in the European Union.[5] Smaller values represent smaller environmental impact.

Experimental

Instrumentation

Power consumption of different LC systems was measured using a CLM 221 power meter (Christ Electronic Systems, Memmingen, Germany) and an ALMEMO 2590 data logger (Ahlborn, Holzkirchen, Germany).

All measurements were conducted at ambient temperature on four different HPLC systems representing typical configurations across the InfinityLab LC portfolio:

1. Agilent 1220 Infinity II LC System with isocratic pump (G4286B)
2. Agilent 1220 Infinity II LC System with gradient pump, autosampler, and column thermostat (G4294B)
3. Agilent 1260 Infinity II LC System, comprising:
   - 1260 Infinity II Quaternary Pump (G7111B)
   - 1260 Infinity II Vialsampler (G7129A) with Integrated Column Compartment (G7130A)
   - 1260 Infinity II Variable Wavelength Detector (G7114A)
4. Agilent 1290 Infinity II LC System, comprising:
   - 1290 Infinity II High-Speed Pump (G7120A)
   - 1290 Infinity II Multisampler (G7167B)
   - 1290 Infinity II Multicolumn Thermostat (G7116B)
   - 1290 Infinity II Diode Array Detector (G7117B)

Columns

- Agilent ZORBAX Eclipse Plus C18, 4.6 × 250 mm, 5 µm (part number 959990-902), used with instrument 1
- Agilent InfinityLab Poroshell 120 EC-C18, 4.6 × 150 mm, 2.7 µm (part number 693975-902T), used with instruments 2 and 3
- Agilent ZORBAX RRHD Eclipse Plus C18, 2.1 × 50 mm, 1.8 µm (part number 959757-902), used with instrument 4

Software

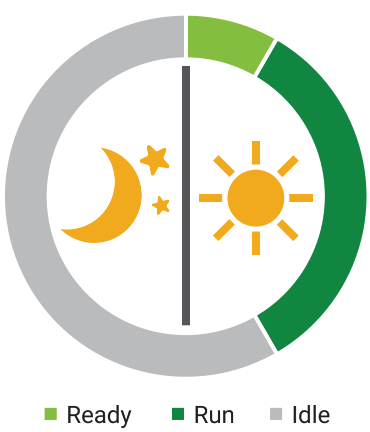
Agilent OpenLab CDS ChemStation edition for LC and LC/MS Systems, version C.01.10 [239]

Solvents and sample

LC gradient-grade acetonitrile and methanol were purchased from Merck (Darmstadt, Germany). Fresh ultrapure water was obtained from a Milli-Q Integral system equipped with a 0.22 µm membrane point-of-use cartridge (Millipak). The sample used for all experiments was undiluted Agilent RRLC Checkout Sample (part number 5188-6529).

Method settings

Power consumption of each instrument was measured during three states of operation over a day in the laboratory: idle, ready, and run (see Figure 2 for exact conditions). The LC system was operated for two hours in each state; average power consumptions were then extrapolated to typical durations of each state. A typical day in the laboratory was assumed to comprise eight hours of actual analysis time on each system ("Run"), with an additional two hours for priming, purging, column temperature equilibration, and waiting for samples to be submitted ("Ready"). A high-throughput (HT) scenario with 16 hours of run time (Figure 3) was calculated in addition to the standard scenario of a 1290 Infinity II LC. For the remaining time of the day, the system was presumed to be in standby, meaning pumps, column oven, and detector were switched off but the autosampler (if applicable) was still cooling the samples ("Idle"). Actual power consumption was measured for two hours in each state and was stable within these two hours; results were then extrapolated to the assumed duration of ready, run, and idle state over a day.



	Idle	Ready	Run
Power	ON	ON	ON
Sample Thermostat*	ON	ON	ON
Column Thermostat**	OFF	ON	ON
Pump	OFF	ON	ON
Detector Lamp	OFF	ON	ON
Autosampler**	OFF	OFF	ON

*Not applicable to Agilent 1220 Infinity II LC Systems.
**Not applicable to isocratic Agilent 1220 Infinity II LC.

Figure 2. Assumed operational states of an LC system over the course of a typical lab day.

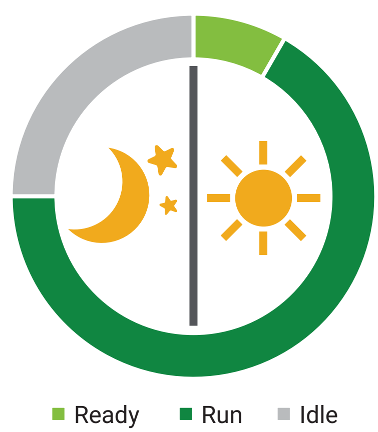


Figure 3. Assumed operational states of an LC system in high-throughput (HT) operation over the course of a day.

During the run state, the chromatographic conditions listed in Tables 1 to 4 were applied on the four systems to separate the sample. Typical conditions according to the capabilities of the examined systems were chosen (for example, a longer run time of 20 minutes for the isocratic LC system versus short run times for the UHPLC-capable instrument).

Table 1. Chromatographic conditions for isocratic Agilent 1220 Infinity II LC.

Parameter	Value
Mobile Phase	Water/acetonitrile, 35:65 (v/v)
Flow Rate	1.5 mL/min
Stop Time	20 min
Injection Volume	5 µL
Column and Sample Temperature	Ambient
UV Detection	VWD 280 nm Peak width >0.1 min (2 s response time) 5 Hz data rate

Table 2. Chromatographic conditions for gradient Agilent 1220 Infinity II LC.

Parameter	Value
Mobile Phase	A) Water B) Acetonitrile
Flow Rate	1.5 mL/min
Gradient	0.00 min 20% B 10.00 min 90% B
Stop Time	10 min
Post Time	2 min
Injection Volume	5 µL
Needle Wash	Water/acetonitrile, 1:1 (v/v) by wash vial
Column Temperature	40 °C
Sample Temperature	Ambient
UV Detection	DAD 280 nm Peak width >0.05 min (1 s response time) 5 Hz data rate

Table 3. Chromatographic conditions for Agilent 1260 Infinity II LC.

Parameter	Value
Mobile Phase	A) Water B) Acetonitrile
Flow Rate	1.5 mL/min
Gradient	0.00 min 20% B 10.00 min 90% B 10.01 min 20% B
Stop Time	12 min
Injection Volume	5 µL
Needle Wash	Water/acetonitrile, 1:1 (v/v)
Column Temperature	40 °C
Sample Temperature	4 °C
UV Detection	VWD 280 nm Peak width >0.1 min (2 s response time) 5 Hz data rate

Table 4. Chromatographic conditions for Agilent 1290 Infinity II LC.

Parameter	Value
Mobile Phase	A) Water B) Methanol
Flow Rate	0.8 mL/min
Gradient	0.00 min 30% B 2.00 min 95% B
Stop Time	3 min
Post Time	1 min
Injection Volume	1.25 µL
Needle Wash	Water/acetonitrile, 1:1 (v/v) by wash vial
Column Temperature	40 °C
Sample Temperature	4 °C
UV Detection	DAD 280 nm Peak width >0.0063 min (0.13 s response time) 40 Hz data rate

Results and discussion

Agilent RRLC Checkout Sample was separated on four different InfinityLab LC systems. Settings and run times were selected in the middle of the performance spectrum (i.e., around 300 bar on systems with a maximum pressure of 600 bar, and 650 bar on the 1,300-bar system). Table 5 gives an overview of the operational parameters and number of samples analyzed per hour. Depending on the application, higher throughput at higher operating pressure could have been achieved. Parameters for the energy consumption measurement, however, were not overly optimized, to represent an average use case of each system.

Figure 4 summarizes the total energy consumption over one day, and the energy needed to analyze one sample on each instrument. Energy consumption increased from the isocratic 1220 Infinity II LC to the 1290 Infinity II LC, which is due to the increasing number of features of the systems: the gradient pump and column thermostat built into the gradient 1220 Infinity II LC added about a fifth to the total energy consumption compared with the isocratic LC. Adding a sample thermostat and switching to a modular setup in the 1260 Infinity II LC doubled the power load compared to the previous system. Higher speed and pressure stability in the 1290 Infinity II LC came with another 20% premium. Running more samples overnight in HT mode added just over 10% to the total energy consumption.

Table 5. Operational parameters and application examples of the systems used. FPP: fully porous particles; SPP: superficially porous particles.

System	Application Examples	Column	Average Pressure	Samples per Hour (per Day)
Isocratic 1220 Infinity II LC	Compendial methods, easy separations, sporadic use	4.6 × 250 mm, 5 µm FPP	300 bar	3 (24)
Gradient 1220 Infinity II LC	Routine separations, compendial gradient methods, non-sensitive samples	4.6 × 150 mm, 2.7 µm SPP	300 bar	5 (40)
1260 Infinity II LC	Routine/optimized separations, compendial gradient methods, sensitive samples (4 °C)	4.6 × 150 mm, 2.7 µm SPP	300 bar	5 (40)
1290 Infinity II LC	High-performance methods, fast gradients, difficult separations	2.1 × 50 mm, 1.8 µm FPP	650 bar	15 (120)
1290 Infinity II LC HT	Same as above, but higher throughput by overnight runs	2.1 × 50 mm, 1.8 µm FPP	650 bar	15 (240)

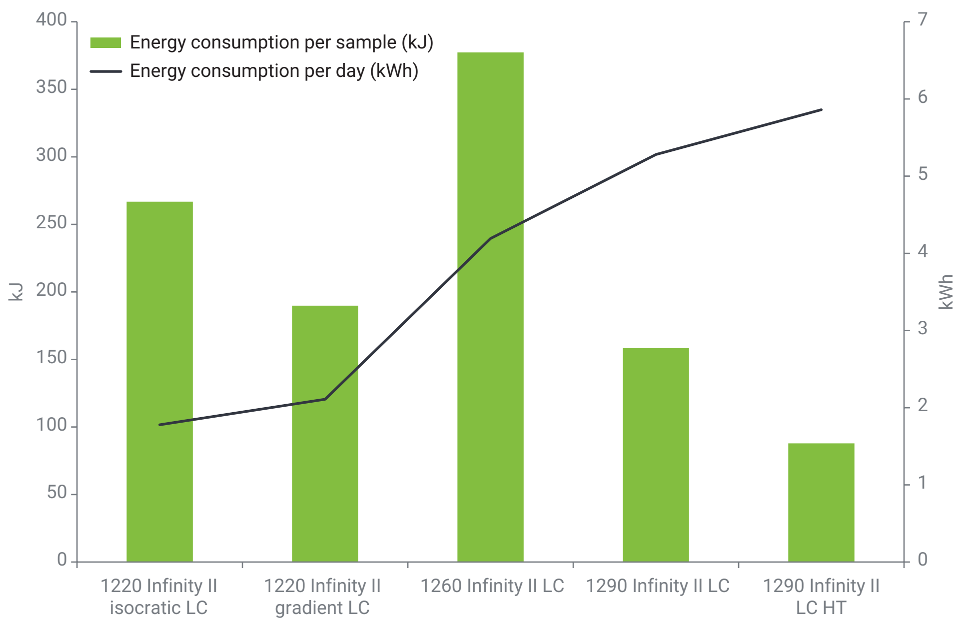


Figure 4. Total energy consumption of the four LC systems per sample (in kJ, left axis) and per day (in kWh, right axis). The fifth column represents the high-throughput (HT) scenario that was calculated for the Agilent 1290 Infinity II LC.

Taking the number of analyzed samples per day into the equation turns this image upside down. The isocratic 1220 Infinity II LC did not only have the lowest energy consumption but also the lowest number of samples. At 24 samples per day, the energy needed for one sample analysis was 267 kJ. The high-end 1290 Infinity II LC, on the other hand, analyzed 240 samples per day in HT operation (16 hours of sample runs), which cut the energy per sample to 88 kJ—a third of the isocratic system. In standard operation (120 samples within eight hours), the 1290 Infinity II LC consumed about 160 kJ per sample. Both the gradient 1220 Infinity II LC and the 1260 Infinity II LC managed 40 samples per day, but their energy consumption per sample lay worlds apart: 190 and 380 kJ, respectively.

Comparing the configurations of these two systems (see experimental section), it becomes evident that the 1220 Infinity II LC was designed to be a compact LC that offers exactly what is needed for basic routine applications at lowest cost: a two-channel gradient pump with 600-bar pressure stability, an autosampler, a column thermostat, and a UV detector. The 1260 Infinity II LC is a modular system, featuring a quaternary pump and a sample thermostat in contrast with the 1220 Infinity II LC. The flexibility of single modules that can be exchanged according to the user's demands certainly comes at an energy-consuming price. Cooling the samples, however, accounted for the greatest part of increased energy consumption.

These results make it evident that, to decide which is the most environmentally friendly system, the intended purpose of the system must be taken into account. Will UHPLC methods be run, which require an extended pressure range? Are samples temperature sensitive and need cooling? What is the typical sample throughput per working day? If these questions are clarified, the energy consumption data presented here helps narrow the instrument choice within the broad Agilent LC portfolio. It also shows that the mode of operation needs to be considered: If the system runs only twice a week, a low overall energy consumption can be more important than low energy consumption per sample. If methods can be adjusted and workflows permit, continuously operating a HT system might be a better economic and ecological choice than running two or three legacy systems.

Conclusion

The ACT label informs about the environmental impact of laboratory equipment. Part of the label is the energy consumption of a product during operation, given in kWh/day. This technical overview presents how the energy consumption of ACT-labeled Agilent LC systems was determined. It shows that not only energy consumption per working day, but more importantly energy consumption per measured sample, determines whether an LC can be an energy-saver. A high-end 1290 Infinity II LC in 16 hours HT operation each day, for example, needs a third of the energy per sample of the integrated, isocratic 1220 Infinity II LC with manual injector. Knowledge about the environmental impact of a laboratory device helps scientists make environmentally informed purchase decisions within the broad portfolio of Agilent LC systems that are in line with their employer's sustainability goals.

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