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Acetone recycling: a case study in the undergraduate teaching laboratory

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Chemistry teaching laboratories use large volumes of acetone which are predominantly disposed of by incineration as non-halogenated waste. At UCL Chemistry we have begun recycling acetone waste generated by students and researchers. Not only does this reduce costs and emissions significantly, it can also be embedded into teaching to educate students on laboratory chemistry emissions and the impact of sustainability initiatives. We have carried out a preliminary life cycle analysis based on our data for a three-month period of recycling acetone in the teaching laboratory, which demonstrates the benefits of the scheme.

Sustainability spotlight

This work primarily fits in with UN sustainability goals: (12) responsible consumption and production, (13) climate action, and (4) quality education. This work documents preliminary results from UCL Chemistry's solvent recycling scheme, which demonstrates a tangible reduction in carbon emissions (13) from acetone (estimated at 66%). It demonstrates recycling of waste that was previously incinerated (12), resulting in 54% (>500 L) reduction in non-halogenated waste for a three-month period. Its benefits to our teaching and student partnerships (4) in terms of culture change and formal teaching are also demonstrated. This work puts sustainability in the spotlight for laboratory education, which is needed as the impact of climate change on students' futures is apparent.

1. Introduction

Research and teaching in chemistry is under increasing pressure to operate within the bounds of the planet's resources.[14,16] Laboratory chemicals are a category of materials that have extremely high embodied (scope 3) emissions associated with their manufacture. At University College London (UCL), after construction, chemicals had the largest emissions of all purchased goods and services. The use of solvents and fine chemicals clearly needs to be examined, and our perception of these chemicals should be away from their being “single-use”, in analogy to the rhetoric surrounding laboratory plastics. The global acetone market accounted for over 8.3 million tonnes in 2024 (ref. 1) and solvents represent the largest process mass intensity in industry.[2] Acetone is widely used in academic laboratories as both a cleaning agent and organic solvent due to its unusual combination of low toxicity, miscibility with water, volatility, effectiveness of solvating many organic compounds, and (relatively) low price. Alongside the carbon cost of manufacture, transport and disposal of acetone, financial costs from purchasing and disposing of virgin solvents can add up rapidly. University teaching must also align with the 12 principles of green chemistry,[3] of which waste prevention is a key item which can be addressed by a solvent recycling scheme. While the scope of these principles has been critiqued and expanded upon, its influence sets a framework for how we view chemical processes.[3] While sustainable acetone production is a growing area of research, there is still a substantial impact of acetone production *via* the cumene process, the most common production method.[4,5] It is not currently a renewable feedstock.[2] In industry, it appears on solvent selection guides between “recommended” and problematic.[6] UCL Chemistry currently spends between £5000 and £6000 per year on virgin acetone. The incineration of acetone has a theoretical yield of 2.27 kg CO_2 per kg acetone, on top of the 2.55 kg CO_2 per kg of acetone generated *via* the cumene process according to a recent life cycle analysis.[4,13] However, despite its ubiquity in teaching, its environmental impact and life cycle is often overlooked by instructors, and therefore by students. A solvent recycling scheme within the teaching laboratory provides opportunity for a direct intervention with measurable results and opportunities to engage students. Such a scheme has precedent; in the UK, acetone is recycled in research labs at the University of Nottingham's Pharmacy Department[7] (with 10 L capacity and less frequent usage), and in the US, at the University of Colorado Denver.[7] Despite these, there has been no publication of energy and throughput data and life cycle, which is described herein, as a case study in the undergraduate teaching laboratory.

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Engaging students in these practices early in their academic careers fosters an awareness of waste, energy, and circular resource use. These habits can aid and influence how future chemists approach sustainability in research, industry, and policy.[8,10–12,15] As universities work towards net-zero targets by 2030, integrating green chemistry solutions in undergraduate education can serve as a carbon reduction strategy and a pedagogical tool.

This case study examines the implementation of a small-scale acetone recycling programme at a UCL Chemistry teaching laboratory. It will evaluate the environmental and financial benefits of in-lab solvent recovery, with a focus on a life cycle assessment and teaching. Additionally, two research groups within UCL Chemistry also recycle their acetone with us, and we have capacity for more to follow suit.

2. The recycling process

2.1 Automated recycling procedure

Solvent is recycled using the Heidolph Distimatic Pro Workstation 24/7. It is an increased scale automated rotary evaporator with an inlet for solvent waste drums, and an outlet to a drum for clean acetone, into which it empties automatically. The water bath temperature and evaporation pressure can be set independently and for acetone are set to 50 °C and 330 mbar respectively. Annotated photographic details are provided in SI Fig. SI1. The entire system cost £40 996 (quote obtained in September 2024), which can be used to compare to cost and carbon savings figures.

Acetone waste generated at the washing up sinks in the teaching laboratory is directly transferred into the inlet tank on the Distimatic (since the optimisation process described below). The inlet tank is graduated for measuring volumes of waste used, just as the outlet tank is graduated for measuring volumes of recycled acetone produced. The acetone produced is periodically analysed by NMR spectroscopy to ensure purity.

Our experience of monitoring the Distimatic indicates that 1 L of recycled acetone can be produced every 20 minutes of running time, roughly 3 L h^{-1} with recovery of approximately 80%. This value varies depending on factors such as the quantity of acetone in the waste as this will affect the rate of distillation, but holds for >80% acetone.

2.2 Preliminary data over a three-month period

When the Distimatic was installed, all non-halogenated waste was combined and recycled but the initial purity of the acetone generated was not high and contained contamination from small amounts of diethyl ether, THF and other volatile solvents (see SI 3.1). When the acetone washing and non-halogenated waste streams were separated, and acetone waste transferred directly from the sinks to the Distimatic, the acetone obtained was much purer (see SI 3.1) with the only noticeable impurity being water. Analysis by North's conductivity method[9] reveals the water content in the recycled acetone to be 3–6%, though this will vary between batches. Acetone throughput volumes and general laboratory solvent waste disposal volumes were monitored during a three-month period of teaching laboratories running March–May 2025.

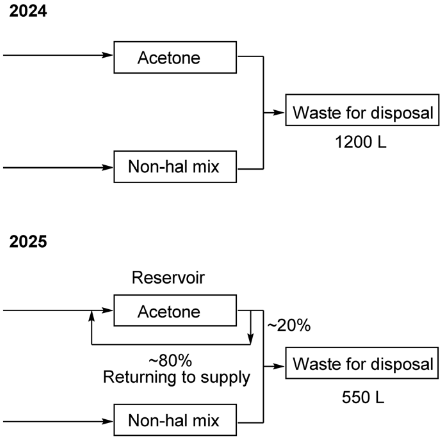

Fig. 1 Schematic of solvent throughput and waste in the teaching laboratory as a flow system.

During March–May 2025 the teaching laboratory disposed of 550 L of non-halogenated waste, compared to 1200 L in the same period in 2024, a remarkable 54% reduction in total waste disposal (including other solvents). It is anticipated that as more iterations of the recycling process happen, and as the system is optimised, this reduction will continue further until a steady state is reached. Between 20th March and 20th May 2025, 212.5 L of acetone went back into the teaching lab supply for washing up, recovered from waste. We acknowledge that some acetone loss will arise from evaporation of acetone used by students, as well as some improper disposal of acetone – not all of the acetone used stays in the waste stream to be recycled. Acetone can go through the system more than once. In this way, the teaching lab can be thought of as an acetone reservoir in a flow system (Fig. 1).

At the time of writing, acetone purchased in UCL Chemistry costs £6 per bottle. For the three-month period analysed herein, 85 bottles were produced, corresponding to a cost saving of £510. In the two months before recycling (Jan, Feb) and the two months post-recycling (Apr, May), 76 fewer bottles were purchased (SI Table SI15) so while this figure is quite variable, as purchasing is done as and when acetone is needed, and will depend on usage, student numbers, *etc.*, there is still a clear decrease. While not a large amount of money on the university scale, this can accumulate over time, as the purchasing declines and the cost of acetone (as is the trend with all chemicals) increases. We have not been able to get an estimate for the cost saving on waste disposal as it is done in bulk centrally, but there will be some modest savings due to the reduction in waste produced.

3. Life cycle analysis

Life cycle analysis aims to estimate the environmental impact of all stages of a product's value chain.[13,20] There are many stages in the life cycle analysis of acetone and exact values for carbon

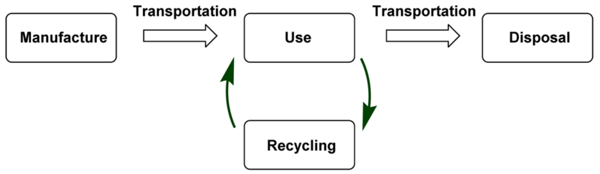

Fig. 2 Overview of the steps considered in life cycle analysis.

emissions are not trivial to obtain. Many parts of the life cycle will be variable, for example emissions due to transport will depend on the size of vehicle, traffic, load weight of cargo, *etc.* Exact values for transportation are impossible to obtain so our numbers are calculated based on representative estimates and sample routes (full details in SI) and are of the correct order of magnitude. Energy usage for each component of the recycler was measured using Energenie ENER007 power meters. For the calculations, we assume that acetone we use is produced *via* the cumene process and disposed of *via* incineration. A diagram illustrating the considerations we made in our LCA is shown in Fig. 2.

3.1 Energy consumption of the recycler

The recycler has four parts requiring electricity; the chiller, the pump, the Distimatic, and the rotary evaporator. Upon measurement, each component used energy at a constant wattage with the exception of the chiller, which fluctuated in its energy use (SI Fig. SI2) so a time-weighted average was used. Based on the fluctuation times and minimum and maximum values, an average value was calculated for the energy consumption of the chiller. Wattage was measured over the time taken to recycle 1 L: 1127 s. Carbon emissions per kWh were calculated using UK government figures from 2023 of 0.196 kg CO_2e per kWh (SI 2.1.3).[17] Costs and emissions from energy usage will vary globally, these numbers are UK-based. The findings for 1 L of acetone are shown in Table 1.

Our measurements suggest that for 1 litre of acetone, 0.045 kg CO_2e are produced by the Distimatic. Correspondingly, for 1 kg of acetone 0.058 kg CO_2e are produced.

3.2 Carbon footprint from manufacture and incineration

Values for manufacture and incineration can be estimated using existing data for the cumene process as standard, and assuming complete combustion of acetone. One-time impacts, such as the manufacture and transport of the Distimatic are assumed to be negligible in the long term, we acknowledge though that it will have impact through its own embodied emissions, with its own carbon payback time. As our acetone bottles are either re-used for recycled acetone (Fig. 3) or recycled, these have also been excluded from the calculations.

3.3 Transport

UCL Chemistry teaching labs purchases acetone from Fisher Scientific that is imported from their facility in Finland. Our mixed non-halogenated waste is transported by Tradebe to Hinckley, who have an incineration facility in Southampton.

Table 1 A table showing the energy usage of each component of the Distimatic, the kWh for 1 L of acetone, and the carbon emissions calculated from UK government guidelines (2025). All values given to 3 sf

Equipment	kWh L^{-1}	kg CO_2e per L
Chiller	0.170	0.0333
Distimatic	0.0115	0.00225
Vacuum pump	0.0415	0.00812
Rotary evaporator	0.00789	0.00154
Total per litre	0.231	**0.0452**

Figures for average HGV lorries emissions were obtained from the UK Government Department for Business, Energy & Industrial Strategy (published in 2025 for year 2023).[17] A sample ferry and road route was used; cumene processing facility to Helsinki (road), Helsinki to Zeebrugge (shipping), Zeebrugge to Teesport (shipping), Teesport to the Teesside Warehouse in which acetone is stored (road), and transit to UCL (road). Using publicly available data for shipping route distances and emissions,[17,18] Google maps data and government data for road distances, it is estimated that transport of virgin acetone to UCL emits 0.2 kg CO_2e per kg. It is important to state that this value is an estimate, but other possible comparable transit routes will have emissions on the same order of magnitude (SI 2.2.2).

Transport of non-halogenated waste is to a storage site in Hinckley to the Tradebe facility in Southampton. This was calculated using the same method; Google maps and government HGV emissions data.[17] It is estimated that the carbon emissions from transport of waste from UCL is 0.04 kg CO_2e per kg (SI 2.2.3).

3.4 Impact of recycling

By far the largest impact on carbon emissions is in the production and incineration of acetone respectively. After the initial three-month period of recycling, acetone purchasing had reduced by 40%, which would in turn correspond to an 66% reduction in carbon emissions (Table 2), assuming no acetone is incinerated. This assumption is discussed in further detail in SI Section 2.3.3. Depending on the assumptions used, using purchasing data to estimate the acetone reservoir (Fig. 1), carbon reduction could be between 54% and 87%, but of course this is still an estimate and should be interpreted as such (SI 2.3.3). While it does take energy to run the recycler, the scale compared with the production and incineration of virgin

Fig. 3 Recycled bottles for recycled acetone.

Table 2 Summary of life cycle analysis. Virgin acetone is given per kg of acetone and the reduced emissions column shows the reduction expected for the same period in the laboratory. See SI Section 2 for details of estimates for transport figures. Manufacture and transport reduction reflects our current purchasing reduction of 40%

Component of virgin acetone	Emissions (1 kg virgin acetone) per kg CO_2	Reduced emissions per kg CO_2
Manufacture	2.55	1.53
Transport to UCL	0.20	0.12
Recycler	0	0.058
Transport from UCL	0.04	0
Incineration	2.27	0
Total	5.06	1.71

acetone is smaller by two orders of magnitude. It is therefore demonstrable that the recycling initiative is significantly carbon saving. With the current cost saving from generation of useable acetone being £510 in the first three months, this corresponds to saving £2k per year, with a payback time for the full Di-stimatic system being roughly 14 years based on this data, though it is anticipated that purchasing will fall further over the course of time too, decreasing the ROI time.

4. Incorporation into teaching

4.1 Cues in the teaching laboratory

Within the teaching laboratory, purchased acetone bottles are re-filled with recycled acetone and labelled clearly as such (Fig. 3). Green stickers are also used on washing up bottles to signify to the students they are using recycled acetone.

These visual cues aim to foster a change in attitudes amongst students, and an awareness that acetone is not "single-use". We propose that students' approach to acetone may change if awareness of its recycling is there. It is documented in the literature that visual cues can challenge learners mindset and re-orient them towards sustainable practice.[8,10–12,15] Actively advertising decarbonisation initiatives provides an opportunity for students be involved and take ownership of their actions, and there is precedented demand amongst students for a greater focus on environmental issues in their courses.[9,10] While development of teaching materials surrounding the scheme is in development rather than demonstrated, the potential is undeniable.

4.2 Use within teaching lab practicals

Recycled acetone can also be used as a reagent or solvent in teaching laboratory reactions, having comparable purity (SI 3.1) to purchased acetone. While the quantity used within reactions is very small (5–10 mL per student for a given practical), the potential pedagogical value of using recycled solvents visibly in this way is great.[8] The pre-existing practicals for which recycled acetone is currently used include as a solvent in the formation of a phosphonium salt for the Wittig reaction,[17,19] and as a reagent in the Aldol condensation (Fig. 4). Expecting the contamination of water with which acetone forms an azeotrope, recycled acetone is not suitable for moisture-sensitive reactions. With preliminary success demonstrated, further practicals will be developed as future work, which align closer with the principles of green chemistry.

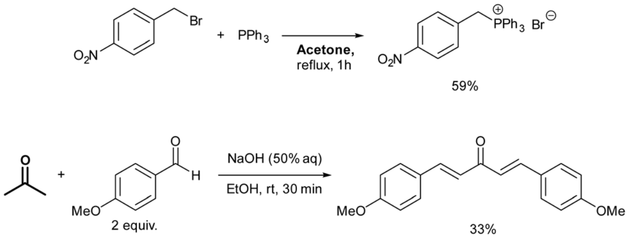

Fig. 4 Teaching lab reactions in which recycled acetone is used.

Table 3 Recycling of cyclohexane/ethyl acetate mixtures. Ratios determined by NMR spectroscopy (SI Section 3.2)

Cyclohexane : ethyl acetate ratio before recycling	Cyclohexane : ethyl acetate ratio after recycling
8.9 : 1	6.4 : 1
7.4 : 2	7.3 : 2
6.4 : 3	6.4 : 3

4.3 Other solvents

Preliminary data has been collected on the extension of the recycling protocol to other solvents. At UCL, column chromatography in the teaching laboratory is carried out using tens of litres of cyclohexane/ethyl acetate mixtures.† As the boiling points of cyclohexane and ethyl acetate are similar (80.75 °C and 77.1 °C respectively at STP), they can be recycled together by co-distillation and reused as solvent mixtures for column chromatography (Table 3). For these solvents, conditions of 50 °C and 145 mbar give good results.

The recovered mixtures can be analysed by NMR spectroscopy and then re-diluted to the desired polarity for the purpose of TLC/column chromatography. As with acetone, triage of waste into dedicated "chromatography waste" containers is necessary to guarantee the purity of the recovered material. Solvents for recycling must have a relatively low boiling point and be part of a separable waste stream. Compliance is key – as shown in the case of acetone, messaging and triage to limit contamination drastically reduces impurities, so behavioural buy-in from all users is essential. One must also consider safety within the principles of green chemistry; while solvents such as dichloromethane and chloroform may fit the volatility criteria, their toxicity and environmental impact compared with solvents such as acetone, require that their use should be eliminated, rather than their being recycled.[2,6]

4.4 Potential as a case study in pre- and post-laboratory exercises

Incorporating sustainability into learning activities, particularly active learning, is a crucial part of students considering the impacts of all areas of their work.[13] Given the nature of the solvent recycling – using thermodynamic principles in the evaporation, using real data to calculate metrics and doing their own life-cycle analysis, identify impurities, *etc.*, – there is potential for incorporation into other parts of the degree, for example, physical chemistry. This is part of the ongoing future work of this scheme.

5. Conclusions

We have developed and implemented an acetone recycling scheme in the UCL Department of Chemistry, with demonstrable cost and energy savings. An initial life cycle analysis suggests the scale of the net carbon savings, currently estimated at 66% In the three-month period 20th March to 20th May 2025, £510 of cost savings were demonstrated through acetone produced. This scaled would achieve direct cost savings of roughly £2000 per year suggesting that the payback time for the Distimatic is around 14 years. Recycled acetone is of sufficient quality to use in teaching lab practicals as both a solvent and a reagent, as well as in washing up, and there is potential to extend the case study into teaching across the laboratory and taught course. The visibility of the scheme to students, and use by other research groups, is contributing to a culture change around solvent use, where the impact is clearly visible by users, and acetone is no longer seen as "single use". Extension of this to other large volume solvents is clearly possible but requires a system to triage different solvents into dedicated receptacles to avoid cross-contamination.

Author contributions

ESM began the scheme, secured funding, gathered initial data and optimised best practice alongside CG and MT who are the technicians responsible for the day-to-day running of the instrument. NG was a summer student, supervised by ESM, who carried out the life cycle analysis and helped gather energy use and other solvents data. ESM wrote the paper text, with contributions from NG.

Conflicts of interest

There are no conflicts of interest to declare.

Data availability

The data supporting this article have been included as part of the supplementary information (SI). Supplementary information is available. See DOI: https://doi.org/10.1039/d5su00926j.

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Notes and references

† Cyclohexane has been chosen as an alternative to petroleum ether as it is safer from an SDS perspective, and has a single boiling point.

1 *Chem Analyst Industry Report*, https://www.chemanalyst.com/industry-report/acetone-market-272, accessed September 2025.
2 C. Jimenez-Gonzalez, C. S. Ponder, Q. B. Broxterman and J. B. Manley, *Org. Process Res. Dev.*, 2011, **15**(4), 912–917.
3 (*a*) P. T. Anastas and J. C. Warner, *Green Chemistry: Theory and Practice*, Oxford University Press, New York, 1998, p. 30; (*b*) P. Anastas, B. Han, W. Leitner and M. Poliakoff, *Green Chem.*, 2016, **18**, 12–13.
4 F. E. Liew, R. Nogle, T. Abdalla, *et al.*, *Nat. Biotechnol.*, 2022, **40**, 335–344.
5 V. M. Zakoshansky, *Pet. Chem.*, 2007, **47**, 273–284.
6 D. Prat, J. Hayler and A. Wells, *Green Chem.*, 2014, **16**, 4546–4551.
7 (*a*) *Radley's*, https://www.radleys.com/case-studies/distimatic-solvent-recycler-for-the-school-of-pharmacy-at-the-university-of-nottingham/?srsltid=AfmBOopShKnJNLJk4FanHnRWYJDKyval54zIslwIqu_PHxzCFNTau3fA, accessed January 2026; (*b*) *CU Denver News*, https://news.ucdenver.edu/recycling-waste-acetone-teaching-laboratories/, accessed January 2026.
8 W. L. Filho, D. Y. Ayal, T. Wall, *et al.*, *Clim. Risk Manag.*, 2023, **39**, 1–16.
9 N. North, *Stud. Conserv.*, 1977, **22**, 197–198.
10 T. Tillmanns, C. Holland and A. S Filho, *Discourse Commun. Sustainable Educ.*, 2017, **8**(2), 5–16.
11 D. Cotton, J. Winter, J. A. Allison and R. Mullee, *Int. J. Sustainability High Educ.*, 2023, **24**(7), 1576–1593.
12 D. R. E. Cotton, J. Winter, W. Miller and L. Dalla Valle, *Environ. Educ. Res.*, 2017, **24**(11), 1611–1626.
13 G. Wernet, C. Bauer, B. Steubing, *et al.*, *Int. J. Life Cycle Assess.*, 2016, **21**, 1218–1230.
14 T. Freese, N. Elzinga, M. Heinemann, *et al.*, *RSC Sustainability*, 2024, **2**, 1300–1336.
15 M. L. Clapson, G. Bannard, G. Daliaho, *et al.*, *RSC Sustainability*, 2025, **3**, 4492–4503.
16 S. A. Matlin, S. E. Cornell, A. Krief, *et al.*, *Chem. Sci.*, 2022, **13**, 11710–11720.

17 *UK Government Greenhouse Conversion Factors*, https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2025, accessed November 2025.

18 *Bednblue Sailing Calculator*, https://www.bednblue.co.uk/sailing-distance-calculator, accessed November 2025.

19 J. C. Warner, P. T. Anastas and J.-P. Anselme, *J. Chem. Educ.*, 1985, **62**(4), 346.

20 S. Hellweg and L. M. I. Canals, *Science*, 2014, **344**(6188), 1109–1113.