# Energy Efficient Project 1

**Leo Lei and Yu Lim**

## 1. Design Decisions

We implemented a write-through cache policy, or when we write we update both L1 and L2 caches. We assume writing to DRAM from L2 cache eviction is an asynchronous operation, and thus we don't increment the global clock. We also decided not to add a dirty bit to the L2 cache: this doesn't affect correctness but does make it a bit less energy efficient if we're writing to DRAM something that is already up to date. This means that our simulator will have more writes to DRAM, contributing to slightly higher energy consumption than a dirty-bit implementation.

## 2. Table of Results

The full table can be found at the link:
[https://docs.google.com/spreadsheets/d/1U3Bf9xLHm_Soe3t3l-DQGZxAp0p-9mnjAW_mKOCOy2I/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1U3Bf9xLHm_Soe3t3l-DQGZxAp0p-9mnjAW_mKOCOy2I/edit?usp=sharing)

| A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|
| | L2 Associativity | Total Time (ms) | Total Energy (mJ) | L1i Access | L1i Misses | L1i Energy (mJ) | L1d Access | L1d Misses | L1d Energy (mJ) |
| espresso | 2 | 0.8224 | 2.8596 | 809368 | 1701 | 0.6136 | 191508 | 1002 | 0.4591 |
| | 4 | 0.8224 | 2.8596 | 809368 | 1701 | 0.6136 | 191508 | 1001 | 0.4591 |
| | 8 | 0.8224 | 2.8596 | 809368 | 1701 | 0.6136 | 191508 | 1002 | 0.4591 |
| spice2g6 | 2 | 0.8955 | 3.163 | 784179 | 2607 | 0.6438 | 216221 | 793 | 0.5018 |
| | 4 | 0.8955 | 3.163 | 784179 | 2607 | 0.6438 | 216221 | 793 | 0.5018 |
| | 8 | 0.8955 | 3.163 | 784179 | 2607 | 0.6438 | 216221 | 793 | 0.5018 |
| doduc | 2 | 1.0732 | 4.8044 | 755193 | 4219 | 0.7254 | 245816 | 2816 | 0.5981 |
| | 4 | 1.0732 | 4.8044 | 755193 | 4219 | 0.7254 | 245816 | 2816 | 0.5981 |
| | 8 | 1.0732 | 4.0844 | 755193 | 4219 | 0.7254 | 245816 | 2816 | 0.5981 |
| li | 2 | 1.055 | 3.8353 | 742254 | 2382 | 0.7131 | 258874 | 4827 | 0.5922 |
| | 4 | 1.055 | 3.8353 | 742254 | 2382 | 0.7131 | 258874 | 4827 | 0.5922 |
| | 8 | 1.055 | 3.8353 | 742254 | 2382 | 0.7131 | 258874 | 4827 | 0.5922 |
| eqntott | 2 | 0.9459 | 3.4281 | 769759 | 217 | 0.6653 | 232495 | 2056 | 0.531 |
| | 4 | 0.9458 | 3.4281 | 769759 | 217 | 0.6653 | 232495 | 2056 | 0.531 |
| | 8 | 0.9458 | 3.4281 | 769759 | 217 | 0.6653 | 232495 | 2056 | 0.531 |
| compress | 2 | | 6.1254 | 721216 | 123 | 0.9248 | 280174 | 12869 | 0.8146 |
| | 4 | 1.4889 | 6.1249 | 721216 | 123 | 0.9248 | 280174 | 12869 | 0.8145 |
| | 8 | 1.4889 | 6.1249 | 721216 | 123 | 0.9248 | 280174 | 12869 | 0.8145 |
| mdljdp2 | 2 | 0.8672 | 3.1322 | 768543 | 1120 | 0.6258 | 232995 | 1437 | 0.4919 |
| | 4 | 0.8672 | 3.1322 | 768543 | 1120 | 0.6258 | 232995 | 1437 | 0.4919 |
| | 8 | 0.8672 | 3.1322 | 768543 | 1120 | 0.6258 | 232995 | 1437 | 0.4919 |
| wave5 | 2 | 0.7578 | 2.6116 | 827600 | 465 | 0.5858 | 172446 | 369 | 0.422 |
| | 4 | 0.7578 | 2.6116 | 827600 | 465 | 0.5858 | 172446 | 369 | 0.422 |
| | 8 | 0.7578 | 2.6116 | 827600 | 465 | 0.5858 | 172446 | 369 | 0.422 |

| A | B | K | L | M | N | O |
|---|---|---|---|---|---|---|
| | L2 Associativity | L2 Access | L2 Misses | L2 Energy (mJ) | DRAM Access | DRAM Energy (mJ) |
| espresso | 2 | 62433 | 798 | 0.9966 | 824 | 0.7903 |
| | 4 | 62433 | 798 | 0.9966 | 824 | 0.7903 |
| | 8 | 62433 | 798 | 0.9967 | 824 | 0.7903 |
| spice2g6 | 2 | 76667 | 976 | 1.1326 | 1044 | 0.8848 |
| | 4 | 76667 | 976 | 1.1326 | 1044 | 0.8848 |
| | 8 | 76667 | 976 | 1.1326 | 1044 | 0.8848 |
| doduc | 2 | 98051 | 2578 | 1.392 | 3122 | 1.369 |
| | 4 | 98051 | 2578 | 1.392 | 3122 | 1.369 |
| | 8 | 98051 | 2578 | 1.392 | 3122 | 1.369 |
| li | 2 | 107962 | 1320 | 1.432 | 1566 | 1.0995 |
| | 4 | 107962 | 1320 | 1.431 | 1566 | 1.0995 |
| | 8 | 107962 | 1320 | 1.43 | 1566 | 1.0995 |
| eqntott | 2 | 81006 | 1595 | 1.1947 | 1735 | 1.037 |
| | 4 | 81006 | 1595 | 1.1947 | 1735 | 1.037 |
| | 8 | 81006 | 1595 | 1.1947 | 1735 | 1.037 |
| compress | 2 | 157277 | 5553 | 2.0441 | 7010 | 2.3419 |
| | 4 | 157277 | 5552 | 2.0441 | 7008 | 2.3416 |
| | 8 | 157277 | 5552 | 20.441 | 7008 | 2.3416 |
| mdljdp2 | 2 | 65447 | 1421 | 1.0488 | 1668 | 0.9656 |
| | 4 | 65447 | 1421 | 1.0489 | 1668 | 0.9656 |
| | 8 | 65447 | 1421 | 1.0489 | 1668 | 0.9656 |
| wave5 | 2 | 48965 | 743 | 0.8713 | 784 | 0.7325 |
| | 4 | 48965 | 743 | 0.8713 | 784 | 0.7325 |
| | 8 | 48965 | 743 | 0.8713 | 784 | 0.7325 |

| A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|
| | L2 Associativity | Total Time (ms) | Total Energy (mJ) | L1i Access | L1i Misses | L1i Energy (mJ) | L1d Access | L1d Misses | L1d Energy (mJ) |
| wave5 | 2 | 0.7578 | 2.6116 | 827600 | 465 | 0.5858 | 172446 | 369 | 0.422 |
| | 4 | 0.7578 | 2.6116 | 827600 | 465 | 0.5858 | 172446 | 369 | 0.422 |
| | 8 | 0.7578 | 2.6116 | 827600 | 465 | 0.5858 | 172446 | 369 | 0.422 |
| tomcatv | 2 | 1.5219 | 7.0929 | 615544 | 88 | 0.9148 | 384462 | 10321 | 0.8571 |
| | 4 | 1.521 | 7.0849 | 615544 | 88 | 0.9144 | 384462 | 10321 | 0.8566 |
| | 8 | 1.5209 | 7.084 | 615544 | 88 | 0.9143 | 384462 | 10321 | 0.8566 |
| ora | 2 | 0.7953 | 2.7377 | 799771 | 354 | 0.5976 | 200251 | 232 | 0.4477 |
| | 4 | 0.7953 | 2.7377 | 799771 | 354 | 0.5976 | 200251 | 232 | 0.4477 |
| | 8 | 0.7953 | 2.7377 | 799771 | 354 | 0.5976 | 200251 | 232 | 0.4477 |
| gcc | 2 | 1.0735 | 4.084 | 779515 | 12708 | 0.7317 | 221471 | 5497 | 0.5921 |
| | 4 | 1.0795 | 4.06 | 779515 | 12708 | 0.7304 | 221471 | 5497 | 0.5909 |
| | 8 | 1.0708 | 4.0586 | 779515 | 12708 | 0.7304 | 221471 | 5497 | 0.5908 |
| su2cor | 2 | 1.1763 | 4.5328 | 737181 | 481 | 0.7725 | 262915 | 3135 | 0.6539 |
| | 4 | 1.1763 | 4.5328 | 737181 | 481 | 0.7725 | 262915 | 3135 | 0.6539 |
| | 8 | 1.1763 | 4.5328 | 737181 | 481 | 0.7725 | 262915 | 3135 | 0.6539 |
| hydro2d | 2 | 1.2171 | 5.406 | 748688 | 887 | 0.7957 | 251439 | 11935 | 0.6715 |
| | 4 | 1.202 | 5.2639 | 748688 | 887 | 0.7882 | 251439 | 11935 | 0.6639 |
| | 8 | 1.197 | 5.217 | 748688 | 887 | 0.7857 | 251439 | 11935 | 0.6614 |
| nasa7 | 2 | 1.0084 | 3.8736 | 802971 | 463 | 0.7049 | 197074 | 2875 | 0.5535 |
| | 4 | 1.0084 | 3.8736 | 802971 | 463 | 0.7049 | 197074 | 2875 | 0.5535 |
| | 8 | 1.0084 | 3.8736 | 802971 | 463 | 0.7049 | 197074 | 2875 | 0.5535 |
| fpppp | 2 | 1.0997 | 4.156 | 700500 | 7768 | 0.725 | 299522 | 5375 | 0.6247 |
| | 4 | 1.0995 | 4.1541 | 700500 | 7768 | 0.7249 | 299522 | 5375 | 0.6246 |
| | 8 | 1.0995 | 4.1541 | 700500 | 7768 | 0.7249 | 299522 | 5375 | 0.6246 |

| A | B | K | L | M | N | O |
|---|---|---|---|---|---|---|
| | L2 Associativity | L2 Access | L2 Misses | L2 Energy (mJ) | DRAM Access | DRAM Energy (mJ) |
| wave5 | 2 | 48965 | 743 | 0.8713 | 784 | 0.7325 |
| | 4 | 48965 | 743 | 0.8713 | 784 | 0.7325 |
| | 8 | 48965 | 743 | 0.8713 | 784 | 0.7325 |
| tomcatv | 2 | 132105 | 8534 | 1.9317 | 13014 | 3.3893 |
| | 4 | 132105 | 8517 | 1.9311 | 12980 | 3.3829 |
| | 8 | 132105 | 8515 | 1.931 | 12976 | 3.3821 |
| ora | 2 | 59542 | 542 | 0.9582 | 605 | 0.7343 |
| | 4 | 59542 | 542 | 0.9582 | 605 | 0.7343 |
| | 8 | 59542 | 542 | 0.9582 | 605 | 0.7343 |
| gcc | 2 | 97584 | 2511 | 1.3965 | 3084 | 1.3637 |
| | 4 | 97584 | 2460 | 1.3944 | 2982 | 1.344 |
| | 8 | 97584 | 2457 | 1.3943 | 2976 | 1.3432 |
| su2cor | 2 | 117751 | 2918 | 1.5779 | 3588 | 1.5286 |
| | 4 | 117751 | 2918 | 1.5779 | 3588 | 1.5286 |
| | 8 | 117751 | 2918 | 1.5779 | 3588 | 1.5286 |
| hydro2d | 2 | 92379 | 5951 | 1.478 | 8923 | 2.4608 |
| | 4 | 92379 | 5649 | 1.4657 | 8319 | 2.3461 |
| | 8 | 92379 | 5549 | 1.4616 | 8119 | 2.3081 |
| nasa7 | 2 | 79890 | 2971 | 1.2386 | 3496 | 1.3767 |
| | 4 | 79890 | 2971 | 1.2386 | 3496 | 1.3767 |
| | 8 | 79890 | 2971 | 1.2386 | 3496 | 1.3767 |
| fpppp | 2 | 107522 | 2209 | 1.4673 | 2797 | 1.339 |
| | 4 | 107522 | 2205 | 1.4671 | 2789 | 1.3375 |
| | 8 | 107522 | 2205 | 1.4671 | 2789 | 1.3375 |

**3. Comment on how L2 set associativity affects the system from the above table**

Overall, the varying associativity levels (2, 4, 8) did not significantly impact the energy consumption for most workloads. For the workloads that saw a change in energy consumption between different associativity levels, generally less energy was consumed at higher associativity levels. For instance with the tomcat instruction set we can see a slight decrease in DRAM access and energy with a higher cache association. This could be attributed to the fact that larger sets could potentially mean less line eviction and thus less of a need to go to DRAM from L2.

**4.**

Our code is included in this zip file. It can also be found at the *GitHub link*: [https://github.com/yellowfish15/cache-sim-ee](https://github.com/yellowfish15/cache-sim-ee)