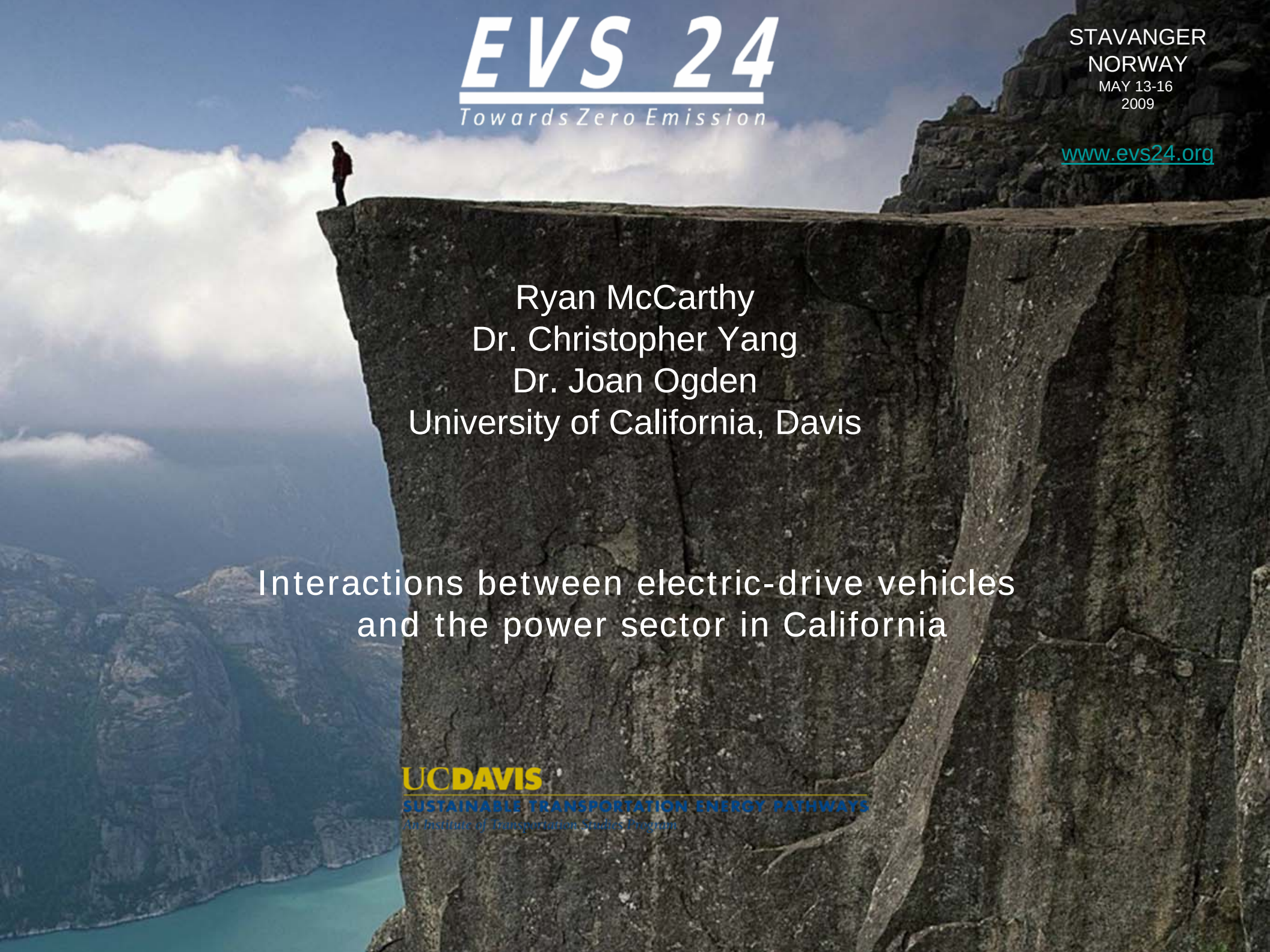


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# Interactions between electric-drive vehicles and the power sector in California

UCDAVIS
SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS
An Institute of Transportation Studies Program


# Summary

- Vehicle demand impacts on current grid in CA
- 3-region model of CA electricity supply (CED)
- In CA, marginal emissions > average emissions
- Electricity emissions sensitive to:
  - Demand quantity, timing, and location
  - Power plant availability (especially hydro)
- LCFS: 80% NGCC, 20% renewables
  - 376 $gCO_2$-eq/kWh


# Findings (2010)

- Based on the assumptions of this analysis:
  - Marginal emissions ~450-500 $gCO_2$-eq/kWh
    - Highest from 6-7pm
    - Lowest rates from 1-7am
  - Peaker sets threshold for PHEV benefit
    - ~650 $gCO_2$/kWh → PHEVs better than HEVs
  - LCFS underestimates emissions by up to 30%

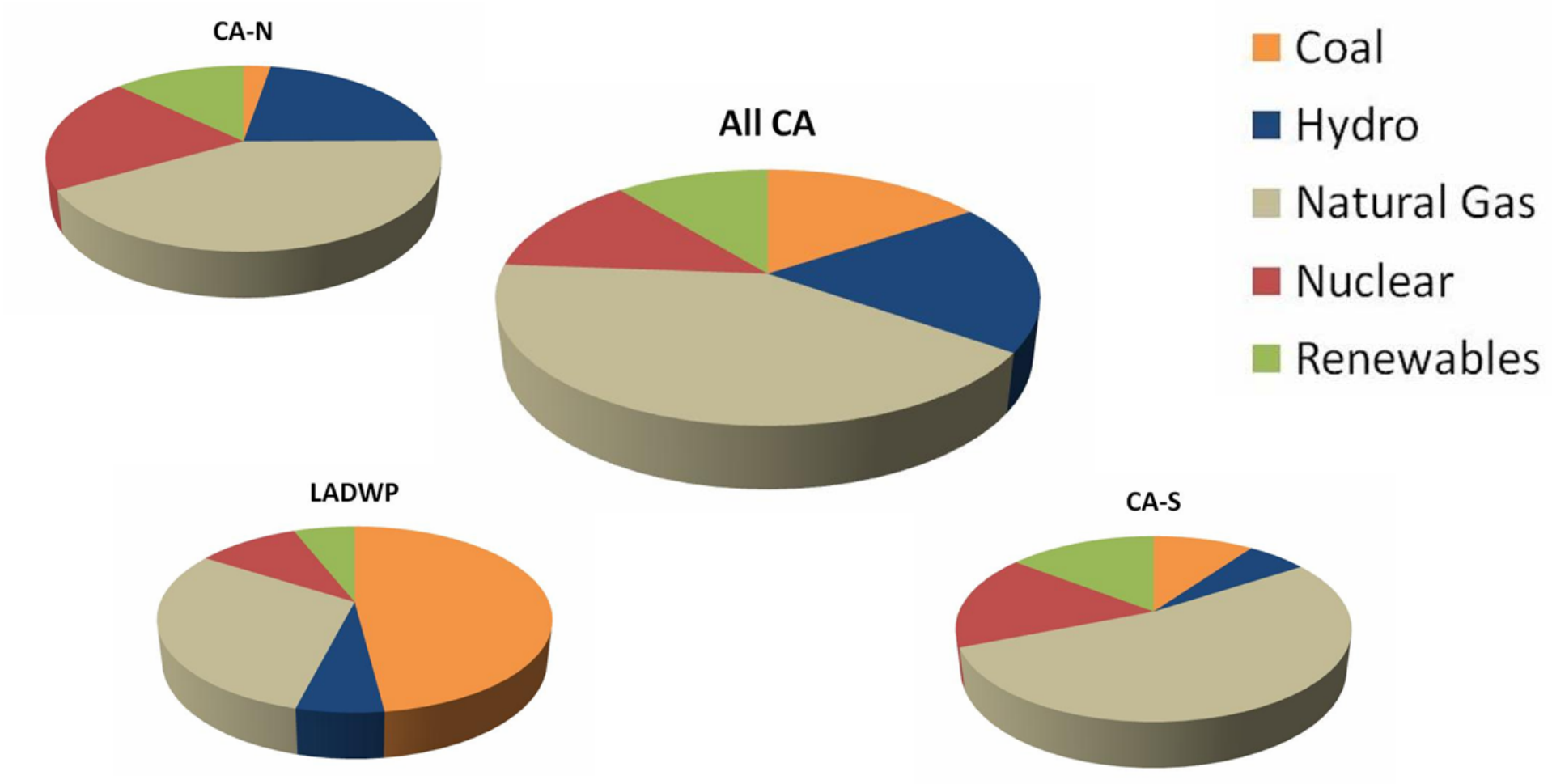

# Outline

- Methods
- Marginal electricity and vehicle GHG emissions
  - Very first vehicles (2010)
  - First hundreds of thousand vehicles (2010)
  - Compare to Low Carbon Fuel Standard


# Methods – CED framework

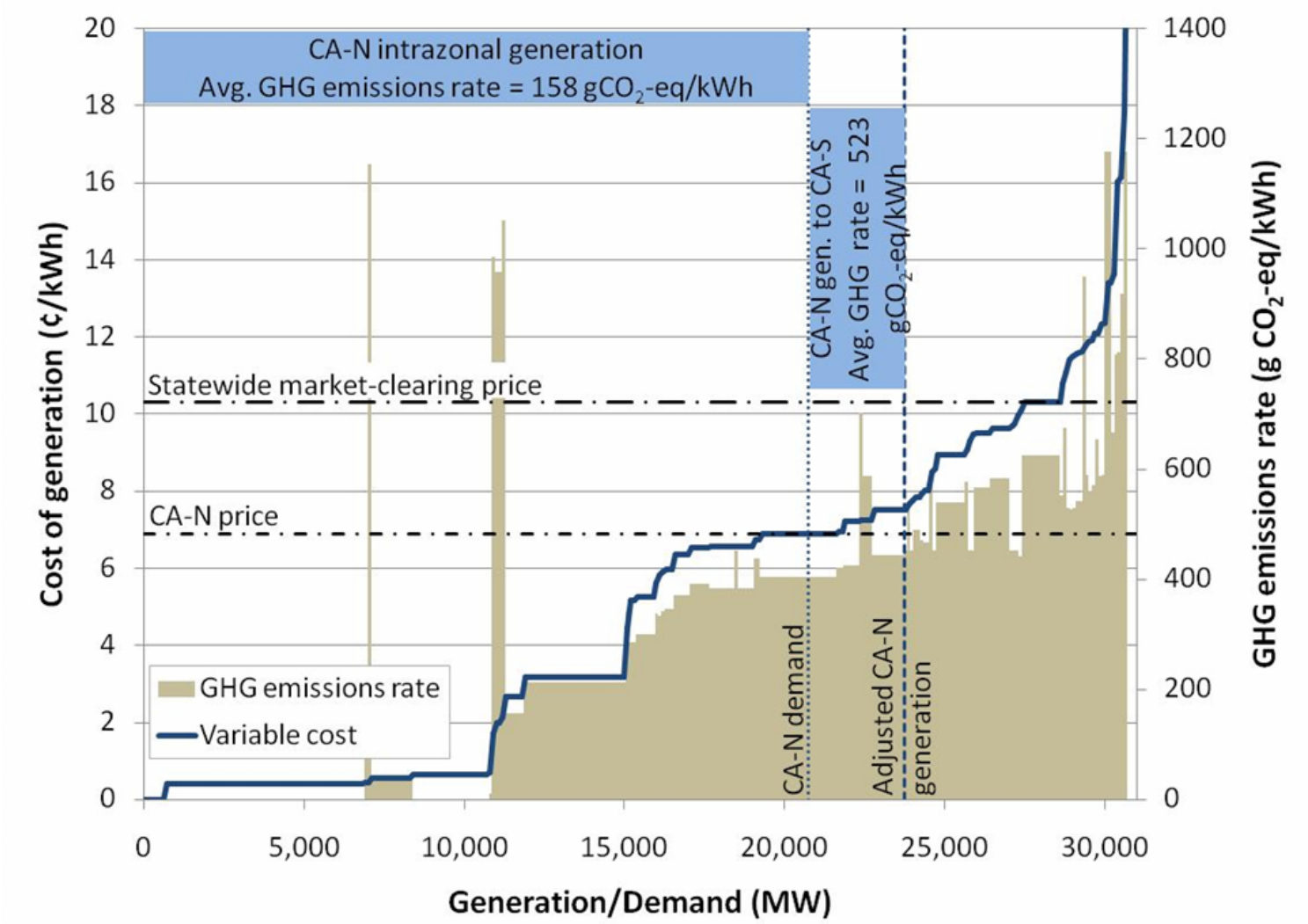
- California Electricity Dispatch (CED) model
- Calculates vehicle demand
- Determines hourly hydro and imports availability
- Allocates generation
  - Nuclear, renewables fixed
  - System imports & hydro as determined
  - Others dispatched to minimize variable cost


# Regional electricity supply

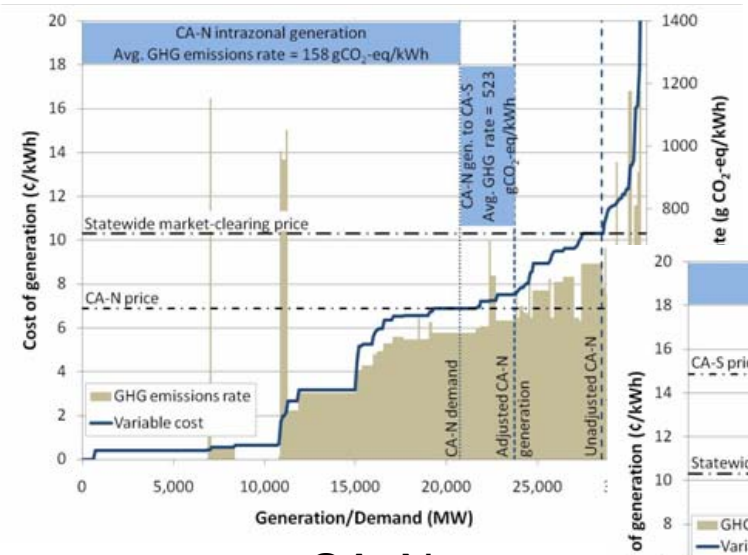



Source: California Energy Commission

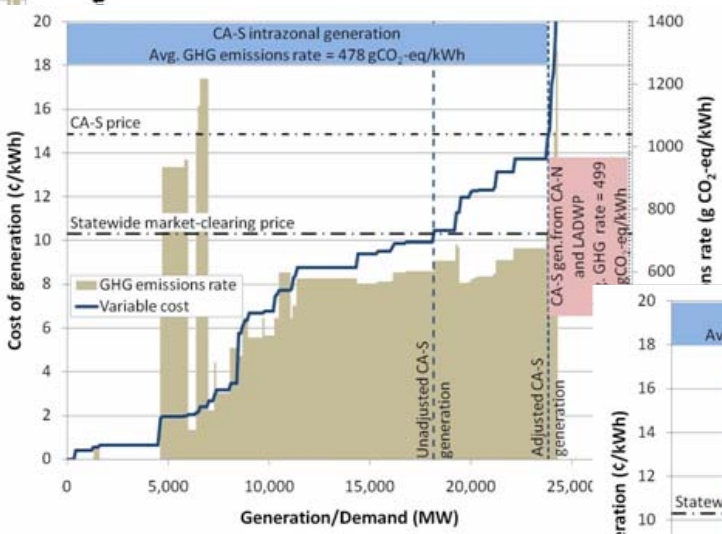

# Methods – Regional dispatch



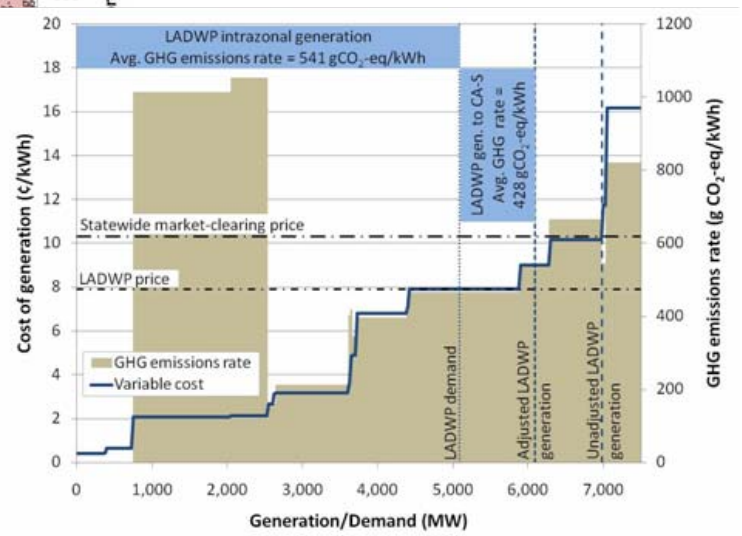

# Methods – Regional dispatch




CA-N

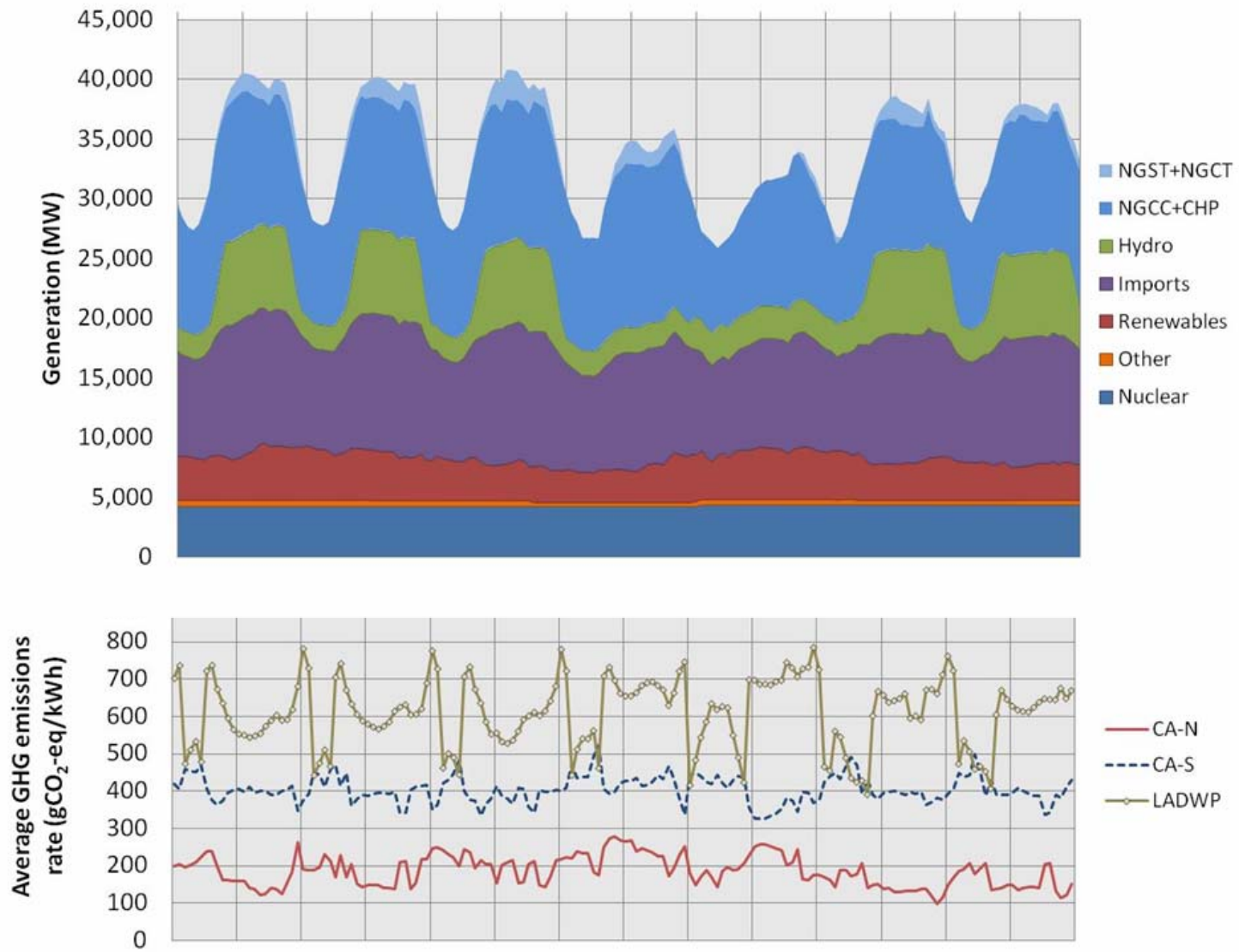



CA-S




LADWP


# Methods – CED outputs




# Methods – Vehicle assumptions

| | Scalar | mpgge[1] | All-electric fraction[2] | Gasoline intensity (gal/mi) | Electricity intensity (kWh/mi)[3] | NG intensity (Btu/mi)[3] |
|---|---|---|---|---|---|---|
| ICE | 1 | 30.0 | --- | 0.0333 | --- | --- |
| HEV | 1.53 | 45.9 | --- | 0.0218 | --- | --- |
| PHEV (ICE mode) | 1.54 | 46.2 | --- | 0.0216 | --- | --- |
| PHEV (electric mode) | 3 | 90.0 | 100% | --- | 0.371 | --- |
| PHEV10 | 1.64 | 49.1 | 12% | 0.0190 | 0.045 | --- |
| PHEV20 | 1.91 | 57.4 | 40% | 0.0130 | 0.148 | --- |
| PHEV40 | 2.18 | 65.3 | 60% | 0.0087 | 0.223 | --- |
| BEV | 3.5 | 105.0 | --- | --- | 0.318 | --- |
| FCV (electrolysis) | 2.32 | 69.6 | --- | --- | 0.780 | --- |
| FCV (onsite SMR) | 2.32 | 69.6 | --- | --- | 0.042 | 2250 |

BEV = Battery-electric vehicle; FCV = Fuel cell vehicle; HEV = Hybrid electric vehicle; ICE = Internal combustion engine; PHEV = Plug-in hybrid electric vehicle; SMR = Steam-methane reformation

[1] Relative vehicle efficiencies based on scalars from GREET model (v1.7), and assuming a new baseline vehicle gets 30 mpg

[2] From EPRI (2007), assuming 15,000 miles/vehicle/year

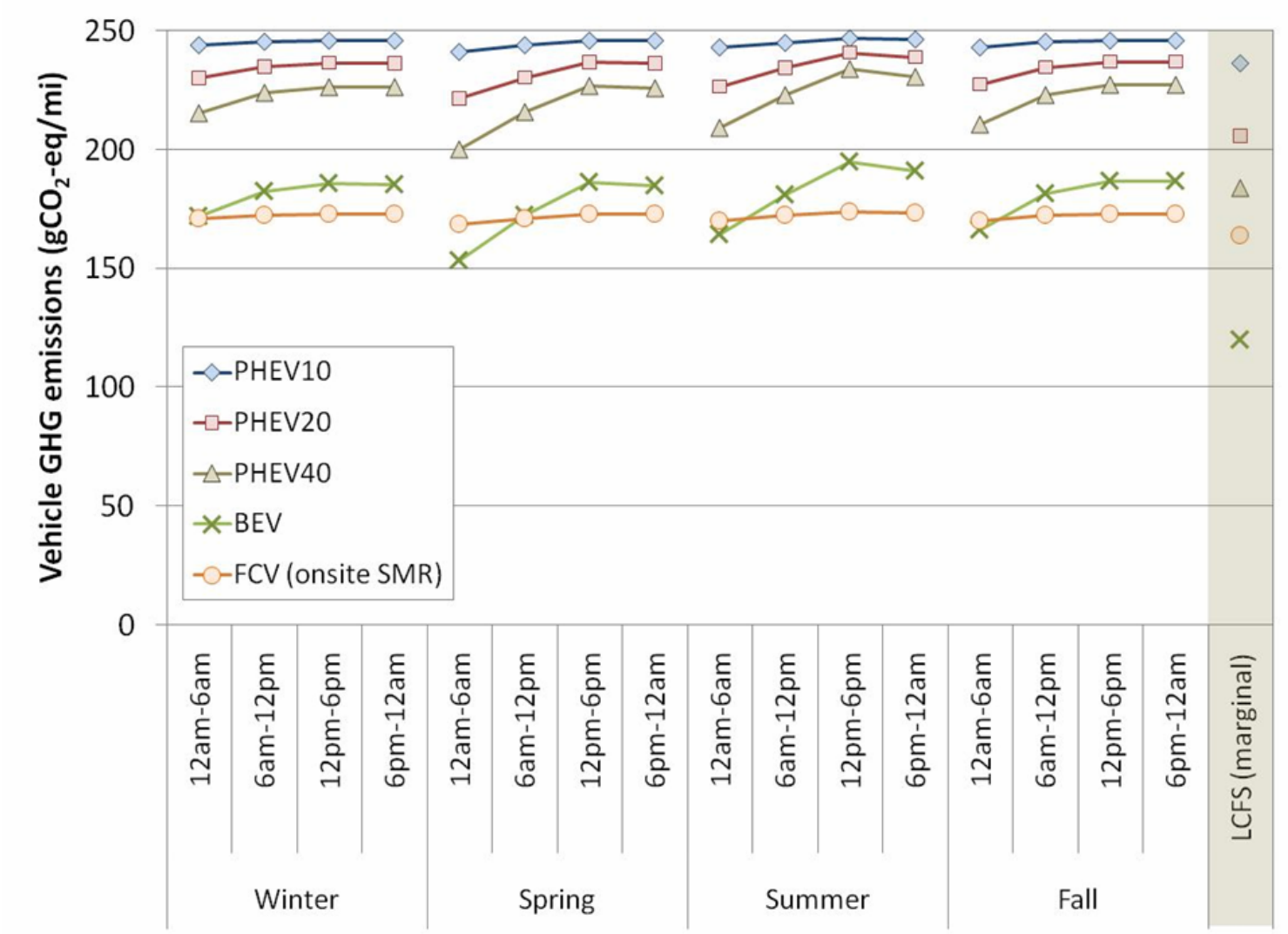
[3] Hydrogen pathway electricity intensity from DOE H2A analysis


# The first 100s – Marginal emissions

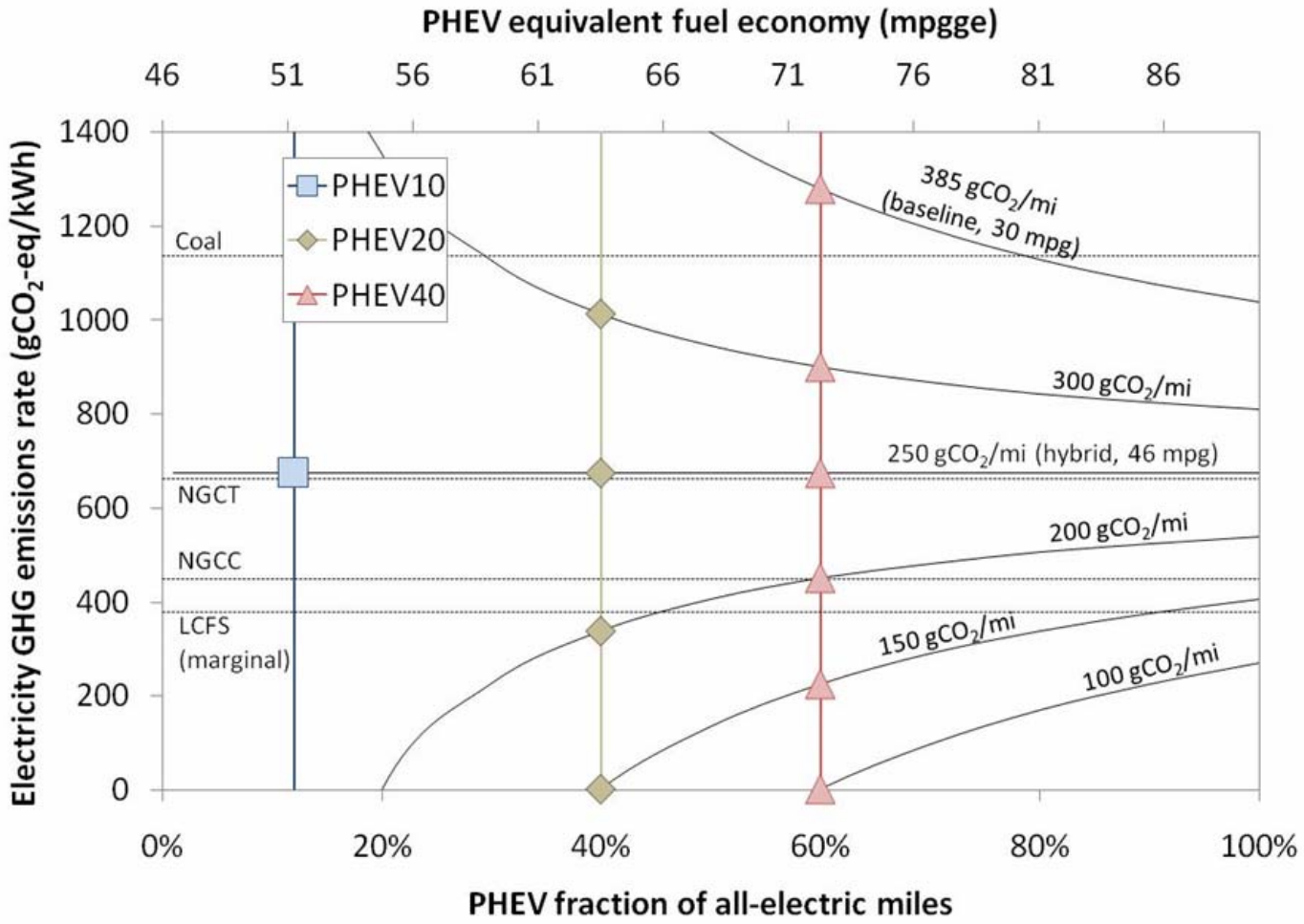
**Average GHG emissions rate from last generator operating (no vehicle demand)**

| Hour | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 612 | 612 | 589 | 546 | 535 | 604 | 609 | 617 | 614 | 598 | 585 | 623 | 595 |
| 1 | 614 | 600 | 555 | 484 | 493 | 578 | 571 | 594 | 574 | 570 | 534 | 605 | 564 |
| 2 | 600 | 578 | 528 | 467 | 510 | 539 | 529 | 557 | 542 | 538 | 498 | 590 | 540 |
| 3 | 609 | 553 | 525 | 475 | 512 | 519 | 515 | 525 | 510 | 515 | 482 | 582 | 527 |
| 4 | 609 | 572 | 549 | 481 | 515 | 532 | 516 | 531 | 523 | 540 | 505 | 592 | 539 |
| 5 | 610 | 607 | 561 | 493 | 513 | 527 | 519 | 575 | 565 | 581 | 559 | 612 | 560 |
| 6 | 613 | 609 | 580 | 514 | 511 | 543 | 554 | 584 | 572 | 587 | 575 | 610 | 571 |
| 7 | 610 | 610 | 604 | 531 | 529 | 564 | 588 | 594 | 604 | 597 | 600 | 611 | 587 |
| 8 | 625 | 620 | 615 | 563 | 584 | 602 | 598 | 620 | 629 | 622 | 607 | 621 | 609 |
| 9 | 627 | 633 | 613 | 596 | 589 | 614 | 615 | 626 | 631 | 628 | 616 | 629 | 618 |
| 10 | 630 | 635 | 625 | 603 | 621 | 633 | 634 | 639 | 626 | 618 | 620 | 625 | 626 |
| 11 | 623 | 640 | 625 | 612 | 639 | 644 | 629 | 635 | 647 | 638 | 626 | 618 | 631 |
| 12 | 632 | 633 | 626 | 609 | 628 | 639 | 650 | 645 | 643 | 632 | 625 | 630 | 633 |
| 13 | 622 | 637 | 620 | 621 | 630 | 642 | 650 | 662 | 643 | 637 | 631 | 626 | 635 |
| 14 | 628 | 637 | 626 | 607 | 625 | 652 | 661 | 686 | 644 | 657 | 633 | 627 | 640 |
| 15 | 627 | 630 | 627 | 606 | 640 | 650 | 651 | 681 | 662 | 643 | 625 | 620 | 639 |
| 16 | 623 | 633 | 631 | 600 | 626 | 658 | 642 | 662 | 675 | 635 | 630 | 631 | 637 |
| 17 | 638 | 636 | 626 | 604 | 641 | 652 | 657 | 663 | 661 | 635 | 625 | 621 | 638 |
| 18 | 642 | 635 | 624 | 608 | 644 | 639 | 655 | 653 | 666 | 646 | 635 | 642 | 641 |
| 19 | 651 | 634 | 621 | 615 | 640 | 639 | 636 | 655 | 662 | 638 | 626 | 629 | 637 |
| 20 | 629 | 612 | 634 | 621 | 622 | 629 | 644 | 655 | 652 | 637 | 631 | 631 | 633 |
| 21 | 637 | 634 | 614 | 619 | 623 | 643 | 642 | 632 | 643 | 647 | 630 | 653 | 635 |
| 22 | 629 | 628 | 624 | 617 | 629 | 640 | 631 | 647 | 634 | 631 | 624 | 621 | 630 |
| 23 | 613 | 612 | 609 | 597 | 604 | 623 | 628 | 643 | 634 | 616 | 610 | 619 | 617 |
| Avg. | 623 | 618 | 602 | 570 | 588 | 608 | 609 | 624 | 619 | 612 | 597 | 620 | 608 |


# The first 100s – Vehicle emissions

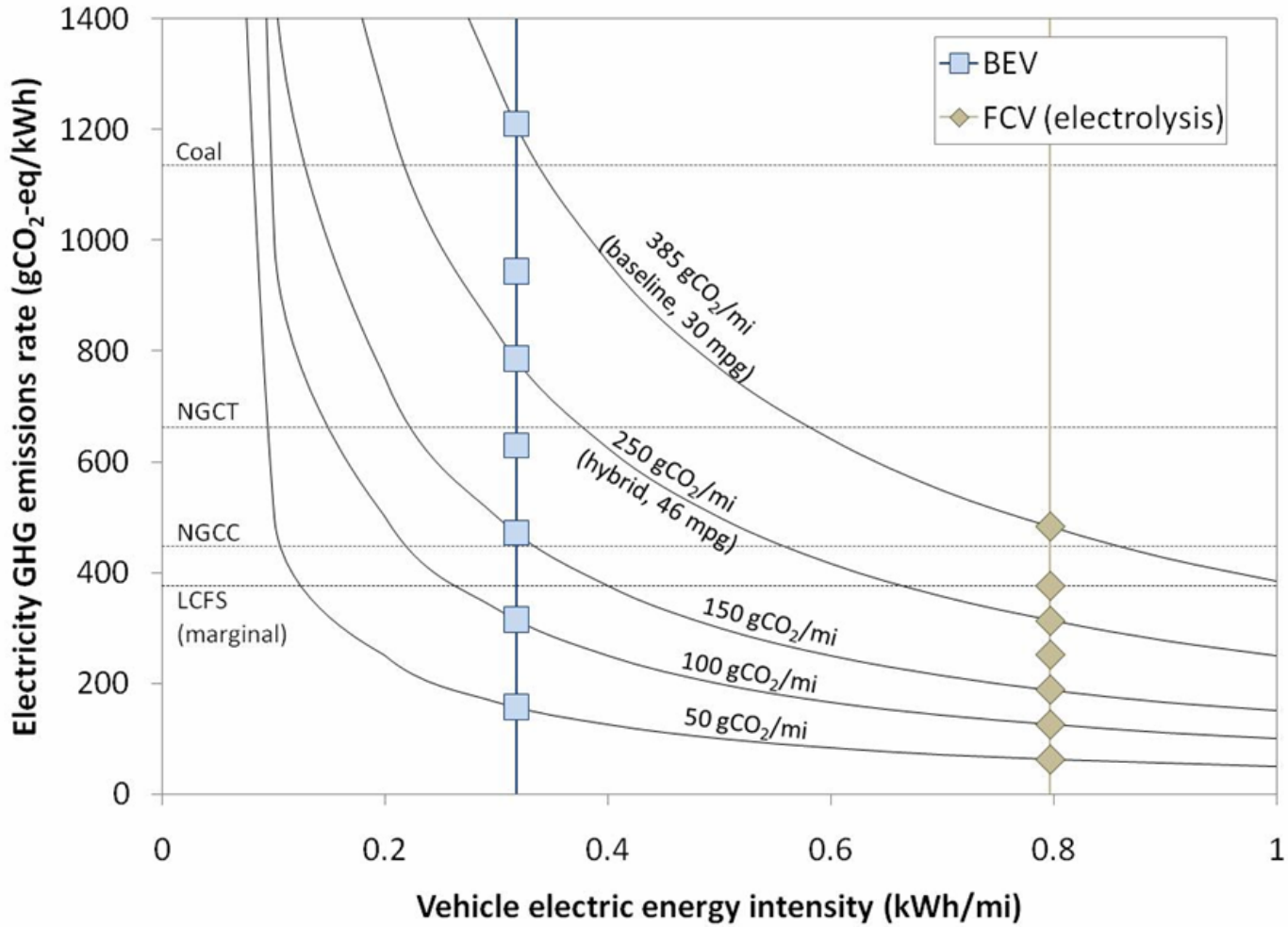



# GHG emission isolines for PHEVs

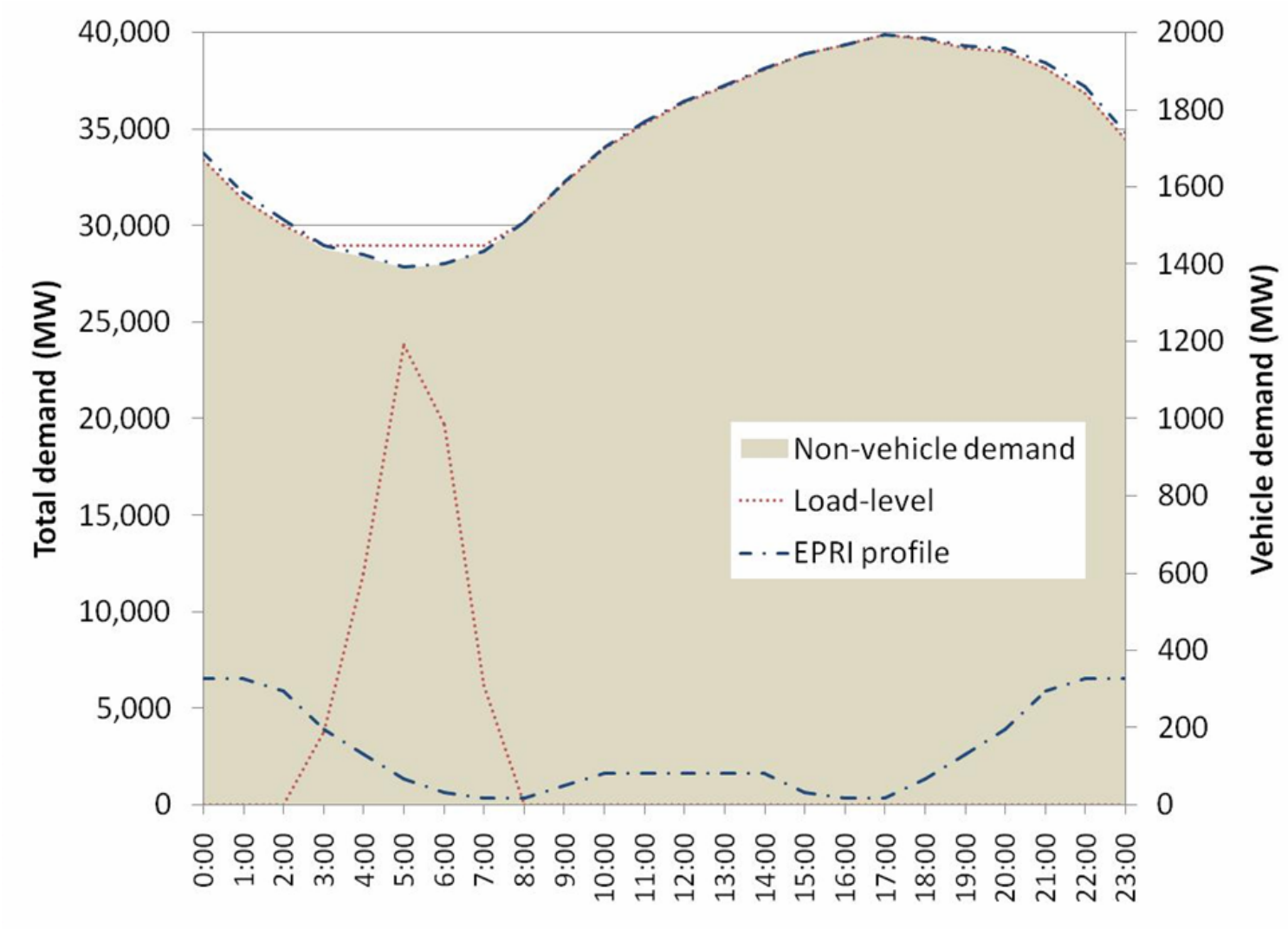



*NGCT plant sets threshold for reducing emissions

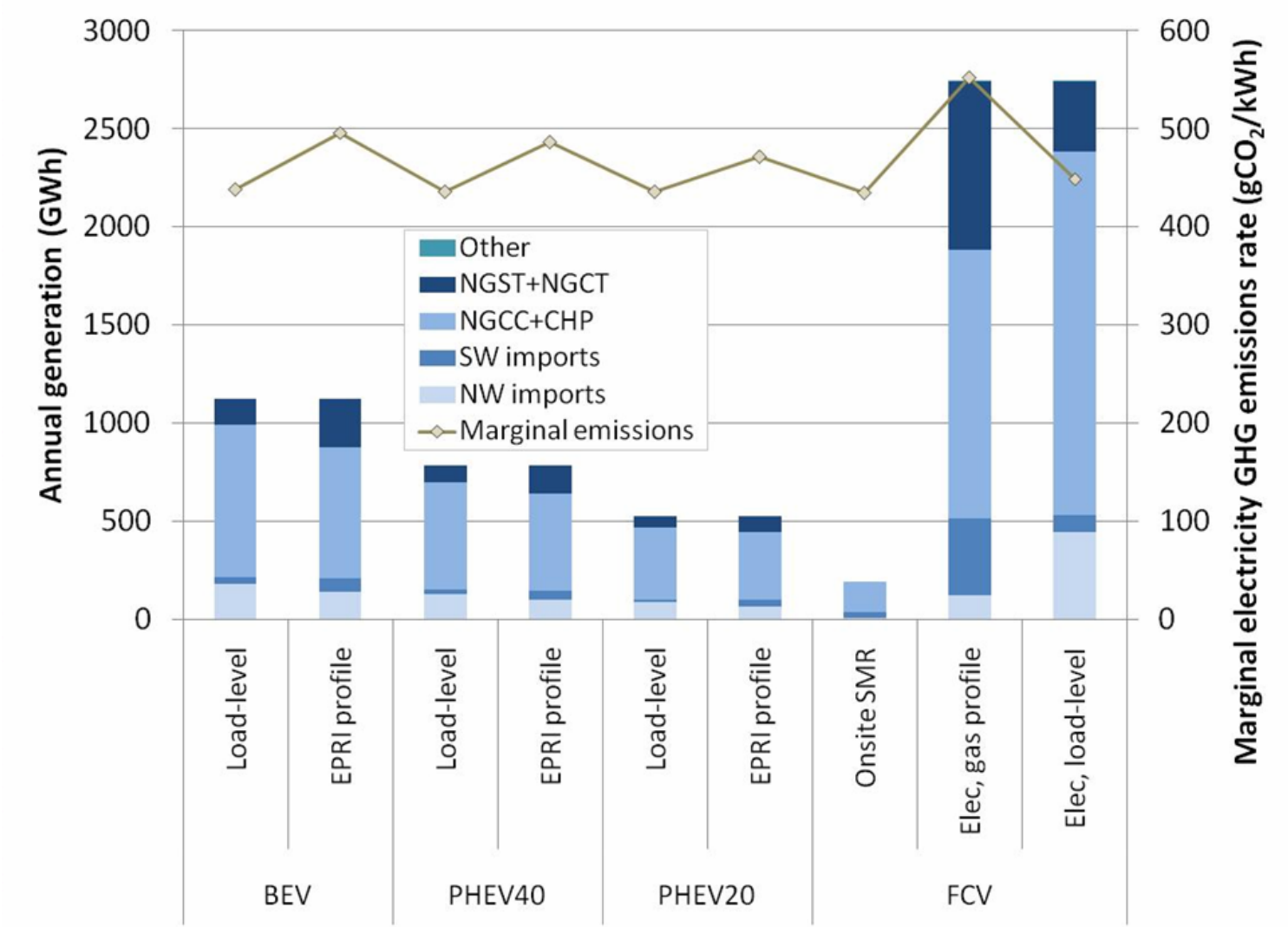

# GHG emission isolines for BEVs, FCVs



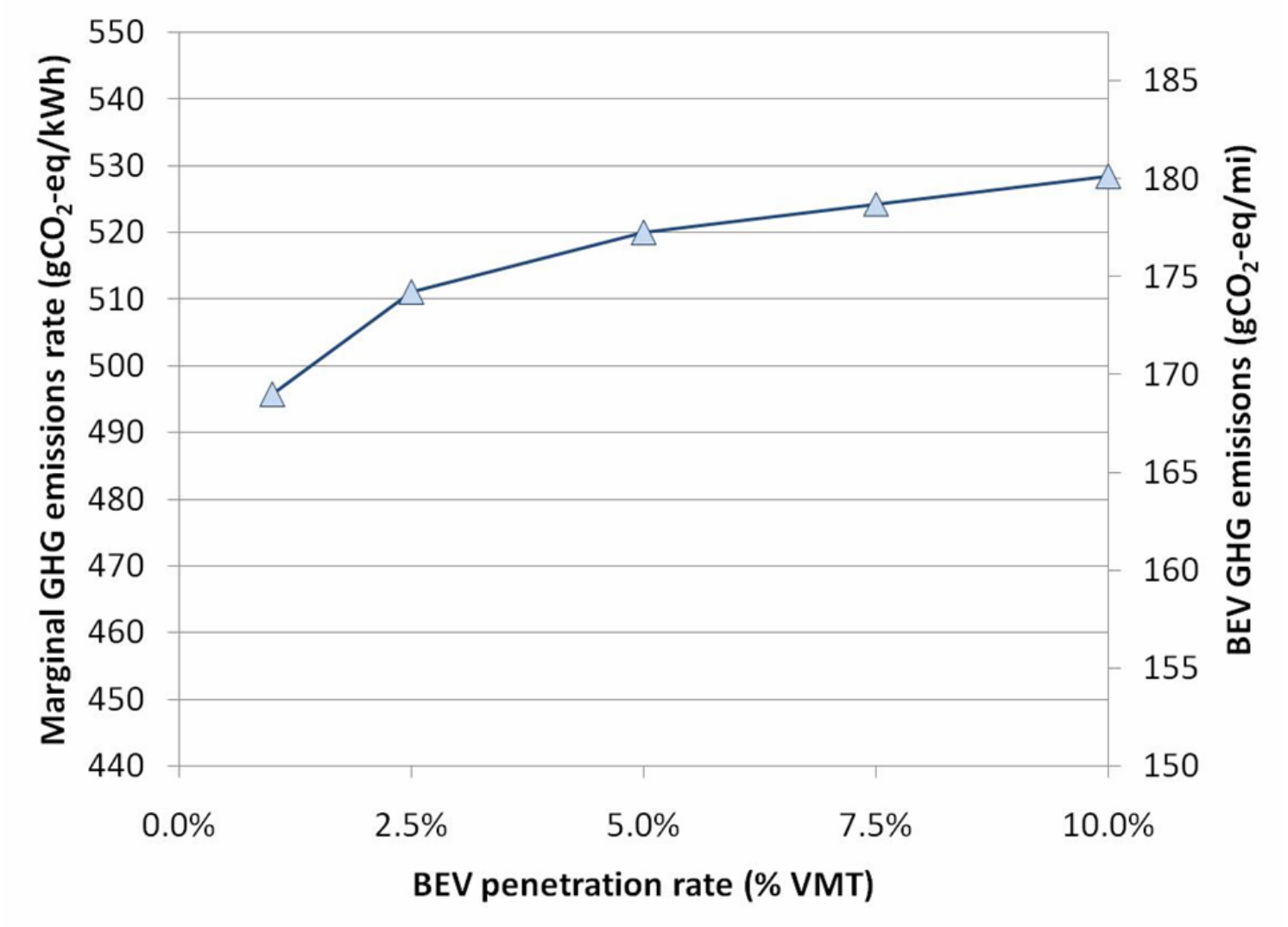

# The first 200,000 – Timing profiles



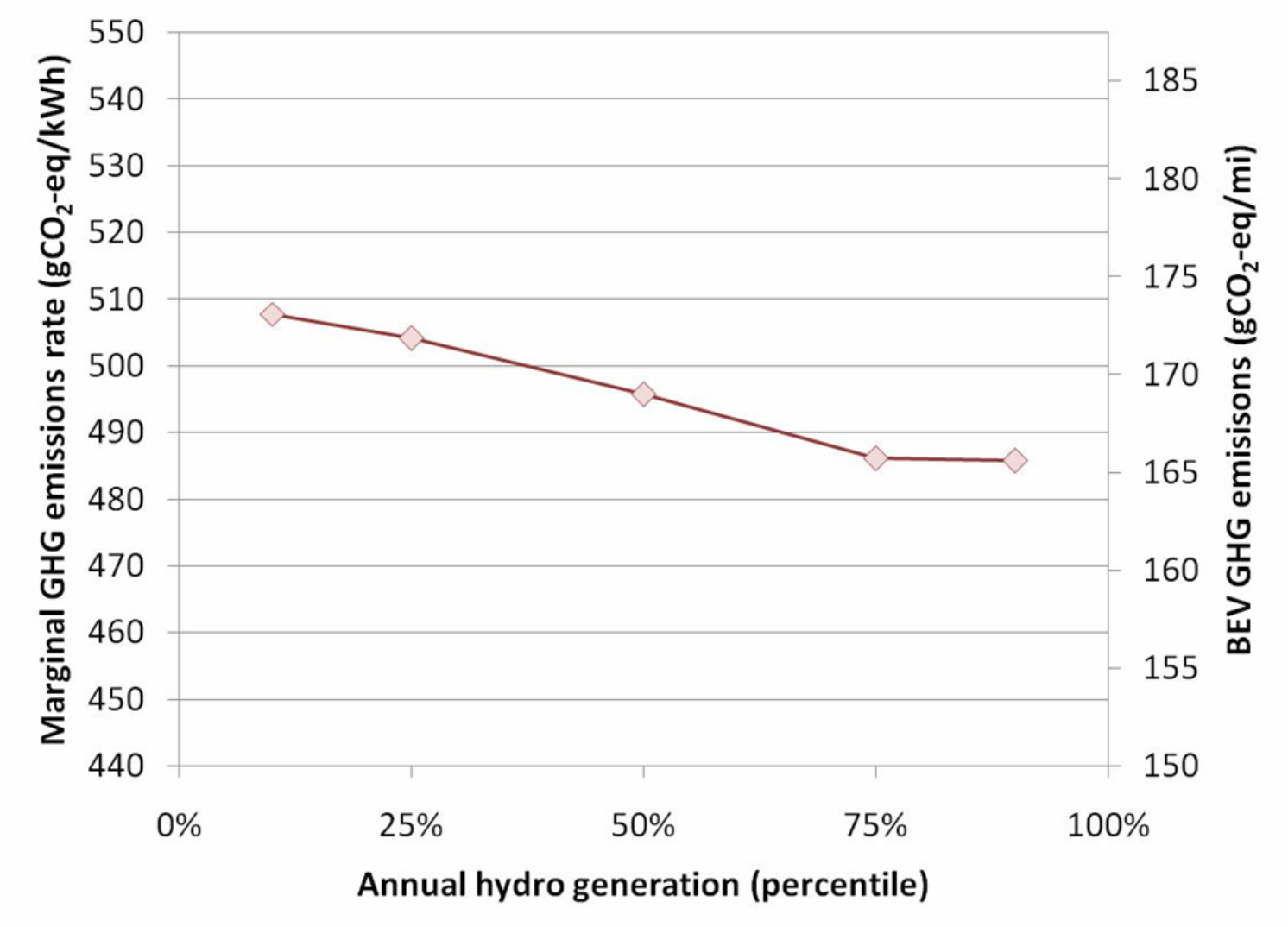

# The first 200,000 – Marginal electricity



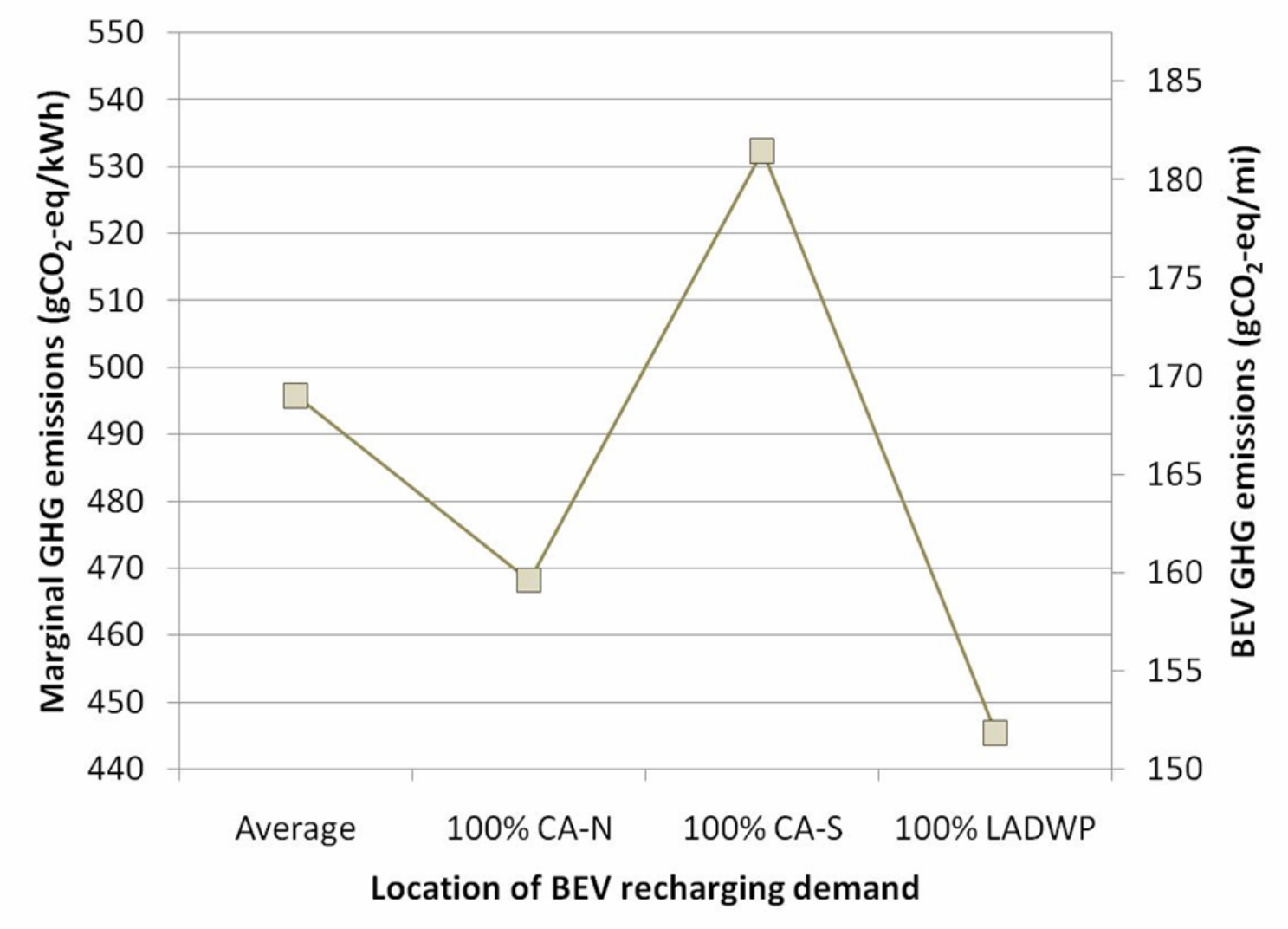

# Marginal emissions sensitivity (BEVs)



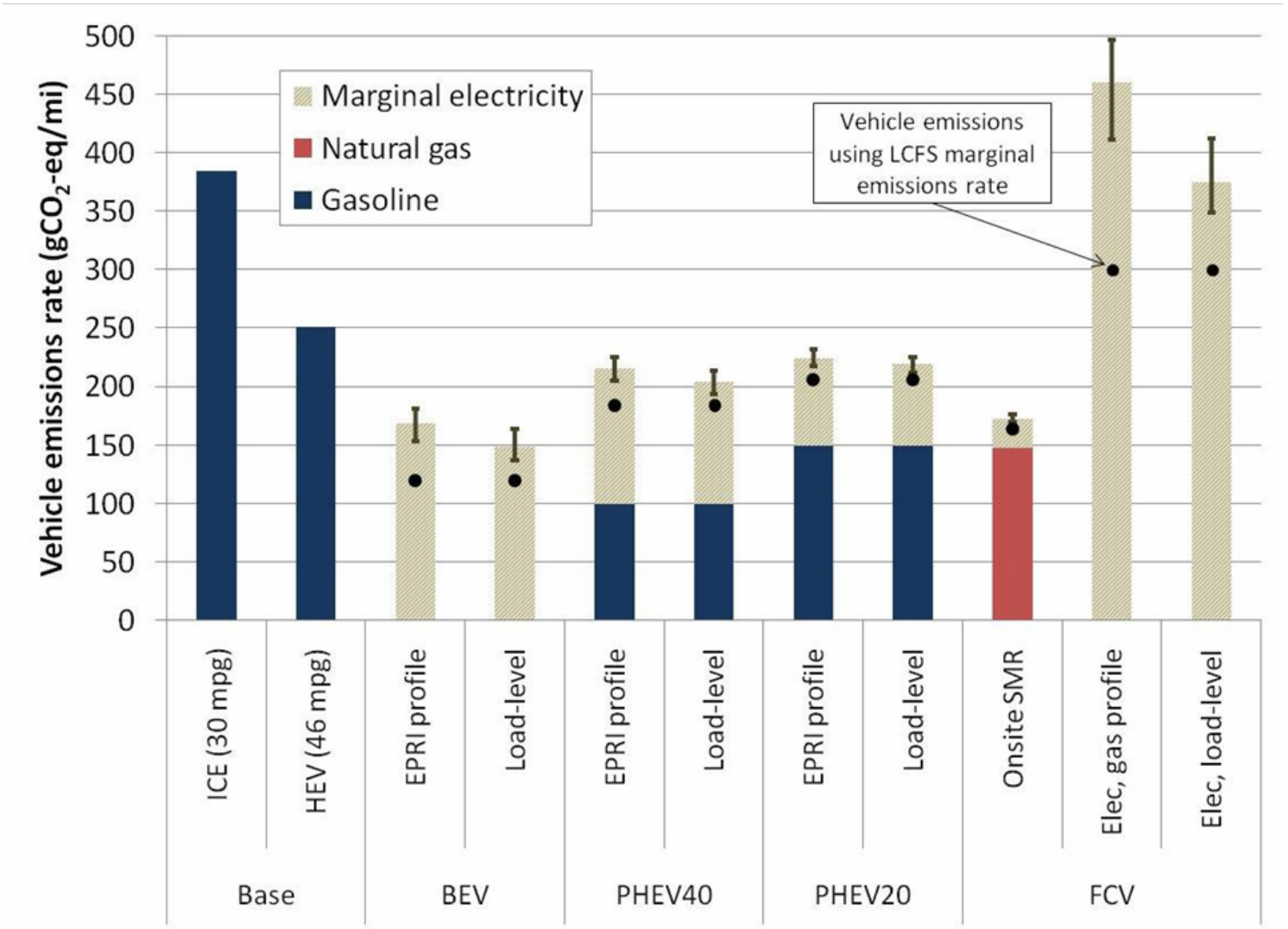

# Marginal emissions sensitivity (BEVs)




# Marginal emissions sensitivity (BEVs)




# The first 200,000 – Vehicle emissions




# Impacts on future grids (2020-2050)

- Preliminary findings:
  - Adding vehicles increases NGCC capacity
  - Adding renewables increases NGCT capacity
    - Wind versus solar
      - Average emissions (solar slightly better)
      - Integration costs (solar slightly better)
      - Marginal emissions (wind quite better)
      - Demand timing impacts integration costs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