84 Topics, Problems, and Questions Suggested for Faculty-Supervised Undergraduate or Graduate Research Projects

The following topics and problems directly or indirectly explore sustainability issues that could benefit from rigorous, faculty-supervised research. Some issues are specific to UC Irvine; others extend well beyond the University. Some of these topics may make more sense if restructured (e.g., interchanging prime and sub-topics), combined, or subdivided.

1. **In order to move toward carbon-neutrality, should the University combust, rather than compost or send to the landfill, combustible wastes?** Is the recovered heat value sufficient to finance the required investment, including an ultra-clean emissions system that meets California air quality standards and is acceptable to the campus community? Note that the cost analysis needs to include all costs and benefits, including capital and operating costs in the business-as-usual case vs. the heat recovery investment/operations case. Also note that the carbon analysis should include emissions associated with trucking to, and placement in, the landfill as well as decomposition and methane emissions in the business-as-usual case. Or, if the landfill option assumes a capped landfill, the cost of methane recovery needs to be factored into that option. Finally, the regulatory and public relations issues need to be thoroughly evaluated, including a public relations strategy to gain acceptance of on-site incineration or "conversion technology" (by whatever name).

2. **An in-depth study of the emerging market for carbon emissions credits and offsets is needed, including an evaluation of whether a market system will really work in yielding the desired environmental objective**, projections of future emissions prices, and an evaluation of whether credits should or should not be purchasable by those who have direct carbon-reducing opportunities that have not been exploited. (In other words, should carbon emissions credits ultimately be limited to industries and sources for which no viable carbon-mitigation alternatives are available, or will it simply be a matter of supply, demand, and pricing?) How does a buyer know that a purchased carbon offset is efficacious? Are any emissions revenues accruing to renewable generators that would have been investment-financed *without* the subsidy provided by emissions credit sales (or does this *matter* if it attracts more investment capital to renewables)? Will the price of carbon emissions credits skyrocket as demand grows and the lowest cost credits are depleted? If the least expensive procurable renewable energy is not price-capped and not subsidized (apart from sales of carbon credits, but inclusive of transmission and distribution costs if remotely-sited), what ultimate price can be predicted for a ton of CO_2-equivalent emissions credit?

3. **Evaluate the relative effectiveness of buying carbon emission credits from sources outside the University vs. channeling the same funding to carbon-reducing projects inside the University.** Some campuses are sending hundreds of thousands of dollars to renewable energy producers as far away as the Midwest (typically, wind farm consortia) while carbon-saving renewable energy projects are stalled just short of financial feasibility. Would it make more sense to create an *internal* system of emissions credits that helps to fund carbon-reducing projects within the University rather than fuel a market that appears to have growing customer demand and that could become pricey? In principle, shouldn't the University be focusing on financing direct, on-site carbon-reducing measures and projects in California before pursuing the easier course of just paying to buy emission credits from distant sources?

4. **An evaluation of the State of California policies, including CPUC regulations and rulings, that need to change in order to foster an accelerated, large-scale response by State government and public institutions to the State of California's goals for reducing carbon emissions.** The underlying premise is that industry and consumers will speak for themselves in seeking such regulatory changes. However, State government and the California public higher education sector warrant an evaluation of policies that, in effect, may thwart the vigorous pursuit of carbon-neutrality. For example, the 1.0 megawatt California Solar Initiative subsidy limit discourages large-scale solar projects. A policy that affects many UC and CSU campuses, limits the Savings by Design rebate program to new building construction, and does not take into account campus-based savings derived from thermal energy storage and cogeneration heat-recovery systems. These and other policy issues need to be evaluated in light of the State's carbon-neutral goals.

5. **An evaluation of whether energy rebates in California stimulate green purchases or not.** Are the rebates large enough to steer consumer choices to green purchases? Have these programs been undermined by participant disillusionment when consumers have discovered that the rebate process involves considerable "red tape," that their rebate application fell outside the specified eligibility period, or that rebate funds had already been depleted? And do rebates really lower prices or simply enable the net, average market price to float upward by an amount that approximates the value of the rebate? Finally, do tax benefits and incentives strike the most effective balance between behavioral and technological strategies?

6. **Do California and federal tax incentives and utility-administered subsidy programs favor the type of energy installations that yield the most greenhouse gas reductions per taxpayer dollar?** For example, would more carbon-efficient subsidies and incentives derive from solar hot water, rather than photovoltaic, rebates? Should more incentive dollars be channeled toward low carbon-emitting automobiles and trucks? Would subsidies or incentives that encourage swimming pool owners to limit pump operation to off-peak hours yield carbon emission benefits?

7. **Traffic signals seem stuck at a primitive level of "smartness" that does not take full advantage of sensor technologies and algorithms that can "learn" recurrent patterns but also respond to episodic conditions.** The mitigation usually considered for intersection congestion involves road widening and intersection expansion, requiring more land and pavement even though the prior conditions probably left a lot of "un-utilized green" intervals that might have been converted to intersection throughput with more optimal signal timing. Orange County provides numerous examples, including Campus Drive and University Drive intersections right at our doorstep. This may be a classic example of land and asphalt solutions vs. sensors and software solutions, with the latter possibly more cost-effective as well as environmentally preferable.

8. **What really kills people in apartment and residence hall fires?** These data are difficult to find, for two reasons: First, post-catastrophe litigation obscures "lessons learned" data behind a wall of secrecy; second, no legislator wants to question code upgrades proposed by firefighters. Yet, there is a legitimate question of whether all the sensing, smoke control, alarm, conduit, and attic separation features now required for new apartment construction by the State's Title 24 are warranted once automatic fire sprinklers are installed in a structure. Have there been any deaths *due to combustion* in fire-sprinklered apartments? Are there documented cases where automatic fire sprinkler systems failed and led to loss of life in apartment fires? If some level of redundancy is required, what is the next-most-important code feature? Overall, can certain legacy fire code requirements be relaxed safely in the presence of automatic fire sprinkler systems? Or, do deaths occur from products of combustion *before* sprinklers activate, raising the issue of whether sprinklers are needed for life safety (as distinct from the issue of reduced property loss) in units that have smoke and heat sensors, smoke control barriers, attic separation, supervised alarm systems, hard conduits, and an enforced no-smoking policy? Since fire sprinkler installations are expensive and require ongoing maintenance, would money be better spent on passive features such as fire blocking and separation, which entail no expense post-installation? It is important to derive analytically sound, data-driven answers to these questions rather than relying on politics and emotion. This is a "green" issue because fire code requirements compete with green features in the development of affordable housing.

9. **In bicycle/pedestrian collisions, what are the typical as well as worst case injury profiles?** What are the typical and worst case types of injuries incurred by pedestrians and bicyclists; and what are average, as well as worst case, recovery patterns? How many bicycle/pedestrian collisions result in insignificant injuries and unreported injuries? Are minor accidents precursors in a pattern that portends more catastrophic occurrences? A rigorous, analytic, data-driven evaluation is needed that is understandable at both a detailed technical level and at a nontechnical level. The National Academy of Engineering has published studies on the relationship of accident precursors and "near misses" to catastrophic events, and there may be data from Europe,

if not North America, that characterize pedestrian and bicyclist injuries sustained in such collisions. Since a greener campus will have both more pedestrians and more bicyclists, we need a better understanding of bicycle safety.

10. **Evaluate the safety, enforcement, and physical circumstances of the pedestrian/bicycle path that extends from Huntington Beach to Seal Beach.** How does the differential "when pedestrians are present" speed limit work? How many accidents occur, and how severe are they to bicyclists and pedestrians, respectively? Given that the path is narrow but mostly straight, level, and visible, are "lessons learned" from this shared-use pedestrian/bike path transferable to UC Irvine?

11. **Are there effective mitigations that can limit bird fatalities where windmills are installed in wind corridors?** Is removal of excavation tailings effective in reducing ground rodents that attract raptors? Are certain airfoil types, sizes, or speeds effective in reducing kill rates? And what is an acceptable level of bird kills, balancing all environmental costs and benefits?

12. **Will students change their food consumption patterns when provided with data, at the point of service, regarding the carbon "footprint" of various food choices?** Rice and beef, for example, carry a bigger carbon footprint than a plate of chicken and potatoes. Do students care enough to alter their food behavior? Beyond the University setting, do non-students care enough to change their habits, for example if this provides "the final straw" on the list of reasons to move away from certain food choices?

13. **Why haven't students adopted electric scooters** as a more popular transportation alternative at Irvine and other campuses? If secure, sheltered parking with electric outlets were provided, would electric scooter usage increase? If electric scooters were equipped with better baskets or "saddlebags" would they gain user acceptance?

14. **What societal factors will ultimately determine whether the "sustainability movement" is, itself, sustainable?** Unlike many social movements, this one will require *decades* in order to succeed, and the movement will have to become truly global. The scale and duration differ remarkably from other social movements in recent history. Will disillusionment set in when people understand the difficulty of reversing global warming? Will people be willing to let future generations inherit this problem, similar to the way other environmental and social welfare problems have been deferred? Will leadership, or political will, or grass roots activism, or education make a difference? Or will "political correctness" disenfranchise people and thus undermine broad-based participation? This is a big, important topic.

15. **What kind of behavioral education, incentives, and persuasion will create broad participation in changing individuals' habits that can collectively yield major**

environmental benefits in a research university setting? For example, what will change people's fume hood usage patterns, their willingness to use task lamps and turn off the lights, their thermostat-setting behavior, their choosing to dress for comfort rather than using energy to make their working environment comfortable, their willingness to discard the electric heaters under their desks, and maybe even give up bottled water? What will make people reactivate the "sleep" features that they disabled on their computers, copiers, and FAX machines? How many dollars could the University rechannel into *non*-behavioral energy conservation systems if motion-sensors, automatic fume hood closers, fume hood presence sensors, and PC energy management software were not needed to counteract individuals' wasteful behaviors? If administrative admonitions cannot change people's everyday behaviors in a "green" direction, what kind of influence process *can* raise awareness and change energy-intensive behaviors broadly, across an entire campus community? How can environmental behavior messages extend beyond "preaching to the choir" to influence a widespread, community response?

16. **Are low-impact hydro criteria too stringent?** Can hydro installations that yield less than 30 megawatts attract investment and make a significant dent on the carbon-neutral agenda? What kind of modeling or metrics can provide an objective and fully inclusive cost/benefit analysis of hydroelectric installation costs and benefits (including the full range of environmental costs and benefits)?

17. **Can nuclear power play a significant role in a carbon-neutral future?** Is there a way to model the costs of nuclear waste security and storage vs. the costs of an equivalent amount of carbon emissions, assuming that the substitute is fossil-fueled? Is there a way to model the national security risks that stem from increased stockpiling of nuclear wastes vs. the vulnerabilities that stem from continued dependence on imported oil? Although these issues have been debated, a comprehensive model is needed that takes into full account all environmental benefits and all risks/costs.

18. **Do laboratory buildings in a research university really need to be open, with full ventilation services, 24X7?** At most UC campuses (including Irvine), two-thirds of campus energy consumption is attributable to laboratories -- in part due to their 24X7 operations as well as their exhaust and air-change (ventilation) rates. What is the cost premium for round-the-clock hours in a typical research lab? Is the main reason for laboratory entry between, say, midnight and 6AM to check experiments that might be monitored remotely if provided with appropriate technology? If so, would remote sensing and monitoring cost less than keeping labs open all night? Are most graduate students occupying laboratories post-midnight studying, or performing lab procedures? The problem is to characterize laboratory operations, occupancy, and risks in the late night/early AM to determine whether air-changes and other energy inputs could be reduced to "setback" levels without impairing research projects or personal safety. Of course the conclusions may differ based on the type of laboratory and research program.

19. **Do research laboratories require high air-changes** (**which is currently standard design practice) now that all lab users are trained to handle dangerous substances and processes in fume hoods?** Does the very existence of high ventilation rates in labs *encourage* risky behavior at the bench -- performing procedures or dispensing materials that should be confined to fume hoods? Does the conclusion vary for different types of labs, procedures, experimental media, or materials?

20. **Do the new laboratory sensor technologies that monitor total VOCs, particulates, CO, and CO_2 fail to detect airborne substances that are potentially present and dangerous at the bench?** Again, does the conclusion vary for different types of labs? For example, where infectious agents exist are air quality sensing technologies insufficient, or do infectious agents attach to particulates or reach a particulate size that would be sensed?

21. **Are there self-diagnosing features that can be built into complex HVAC (heating/ventilation/air conditioning) systems that can, in effect, provide continuous commissioning via the energy management system** (similar to diagnostic sensors and codes that pinpoint problems in modern automobiles)? Can the installation expense of such HVAC (heating/ventilating/air conditioning) sensors be reduced by wireless technology rather than hard-wiring? Do currently available continuous commissioning technologies realize the full potential of digital HVAC control systems?

22. **Is there a simple, snap-on, inexpensive, self-contained (portable) device that can count user actions** such as flushes, freezer door openings, fume hood openings, hand drier usage, etc. by sensing user presence, user touch, or sound? A simple, economical, all-purpose counter would go a long way in facilitating the collection of individuals' frequency-of-use data.

23. **Are any conventional construction materials actually greener** than current green favorites such as cork flooring, hemp fabrics, linoleum, wool carpeting, and sustainably-harvested hardwoods?

24. **Is tree-planting beneficial to greenhouse gas emissions?** A complete analysis needs to take into account both direct impacts, including all facets of the carbon cycle such as soil disturbance, and indirect effects such as shading of structures and pavement.

25. **Who should pay for commuters' carbon emissions?** Should employers bear this responsibility -- in particular, should signatory colleges and universities assume responsibility under terms of the University Presidents' Climate Commitment? Does it matter that, had these employees not been working for the University, they would be commuting *somewhere*? Should the cost of carbon emissions be passed along to commuters, themselves -- keeping in mind that commuters who drive the longest

distances tend to be lower paid than those who can afford to live in campus host communities?

26. **Why does the third-party business model work for a renewable energy project when the University cannot make such a project feasible**, **even with tax-exempt capital?** Is the private sector smarter, more agile, and more motivated? Or is the answer simply that tax advantages such as accelerated depreciation and the investment tax credit more than offset the incremental cost of taxable debt and investor profit?

27. **Is there an environmental rationale that would support, as a matter of policy, limiting beverage sales to one type of container?** For example, if the net carbon emissions associated with recycling aluminum cans are less than that associated with glass or plastic containers, should the campus ban the latter in terms of on-campus sales? In addition to analyzing life-cycle carbon emissions, the potential handling savings of recycling one container type need to be included.

28. **Is there a simple shower drain technology that will divert the first increment of drainwater to the sanitary sewer and the (cleaner) remainder drainage to a wastewater recovery system?** Would some variant of the "first flush" separators used for stormwater work? How much treatment would the resultant recovered water require before reusing it for toilets and urinals? For irrigation?

29. **Should the Orange County Nature Reserve adopt an evaluative process for land transfers in/out of the Reserve that weighs the relative habitat value** of parcels being added or removed, rather than apply an unweighted net acre-for-acre policy? Would <1:1 be warranted if habitat-rich acreage were being traded for habitat-poor acreage, and vice-versa? Can a workable, weighted evaluation framework be derived from the Reserve's stated mission and objectives? Can a weighted land transfer evaluation policy be sold to State of California and federal regulators?

30. **Design a "plug and play" LED strip that replaces a T-8 fluorescent lamp without changing the (standard, solid-state) ballast, the diffuser, the reflector, or the sockets.** Such a lamp needs to have equivalent illumination efficacy (spread and color when used with the existing luminaire), yield a six-year simple payback, and be approved by Underwriters Laboratories. If these design and economic objectives are achieved, the adoption rate among institutional facilities managers will be astounding. Therefore, while it is assumed that product development will involve an area firm working on new LED applications, a business plan will be needed to scale-up production if prototype product development is successful. UC Irvine will probably be able to provide a beta test site, although the University cannot fund product development or pay an uneconomic price for re-lamping.

31. **Evaluate the socioeconomic consequences of increased usage of bio-fuels.** Claims about the socioeconomic and environmental impacts of bio-fuels vary. Some reports warn that bio-fuel demand will raise the price of food, land, and agricultural products in impoverished countries, and result in deforestation. An alternate view says that bio-fuel demand will bring marginal acreage into productive use, create job opportunities for farmers in poor countries, and provide clean energy for millions. Assess the impact of increased bio-fuel production from various types of biomass such as corn, soybeans, flaxseed, rapeseed, sugarcane, palm, algae, and jatropha. A complete analysis will encompass energy input vs. net energy derived, water requirements, secondary and tertiary impacts such as arable land changes and crop substitutions, and overall socioeconomic impact. An objective, comprehensive, nuanced evaluation is needed that differentiates among various biomass sources.

32. **Evaluate the most cost-effective power delivery technology for the proposed Irvine public transportation system being planned in connection with the Great Park.** Early reports suggest that overhead electric ("trolley") lines will be installed for a major part of the proposed system. However, trolley lines entail visual, safety, infrastructure, and maintenance issues and costs that need to be weighed against the expense and benefits of other forms of power delivery. There may be a better way to deliver clean power that will be equally carbon-efficient but more cost-efficient. Since the mode of power distribution affects the design of a transportation system and the associated infrastructure, this analysis needs to proceed early.

33. **Design an absorption chiller for a bus that recovers the waste heat of exhaust gas rather than relying on a compressor refrigerant cycle.** This study could supplement the evaluation suggested above. Absorption chillers are probably too large and heavy to be installed on automobiles, but a bus may prove more feasible, especially if regenerative braking recovers most of the additional kinetic energy associated with a heavier air conditioning unit.

34. **Design a circuit breaker, capable of plugging into a standard breaker panel, that has an embedded sunrise/sunset clock (or a wireless link to a central sunrise/sunset clock).** Many lighting circuits in this and other institutions rely on archaic mechanical timers that are frequently wrong due to power interruptions and simply because the daylight interval constantly varies. What is envisioned would be a plug-in circuit breaker that contains logic and parameter settings for longitude and latitude, providing on/off switching without maintenance or resetting for the life of the device. Of course it has to be cost-effective.

35. **Determine the class scheduling and campus programming changes needed to reverse the Thursday-to-Monday exodus from the campus.** The pattern of thousands of student residents driving home for a long weekend almost every week is certainly not "green," not only due to the driving emissions created but also because of the

inefficiency of underutilized capital assets of the University, compared to more facility usage on Fridays, Saturdays, and Sundays. If the University is serious about becoming carbon-neutral, even such unchallenged traditions as the instructional schedule will need to be reconsidered in terms of impact on the institution's carbon emissions.

36. **Determine how much carbon sequestration could accrue from hedgerow planting of trees along all the edges, fences, and field transitions of all UC agricultural reserve lands, State-wide.** In some parts of the country one sees hedgerows of closely-spaced trees separating fields and encircling farms; in other areas this practice has never been established or it has been abandoned. If UC were to adopt a widespread program of hedgerow tree planting, would it make a significant dent in the University's carbon footprint?

37. **Evaluate student support for an initiative to create a "green leverage" fee.** A "leverage" fee would not fund entire green projects; rather, it would be earmarked to bridge the feasibility gap that would otherwise keep nearly-feasible projects from getting launched. For example, if the campus can afford to pay $0.13 per KWH to buy solar energy from a third party provider who would design, finance, install, and operate photovoltaic arrays shading the top decks of our parking structures, but the best market price for such an arrangement is $0.15 per KWH, the "leverage" fund would pay the two cent differential (times the project's annual output). A student oversight board would evaluate projects and set priorities based on projected carbon savings per unit of investment. How much would students be willing to assess themselves for such a fund? How could such an initiative be promoted so as to maximize student interest, involvement, and support?

38. **How effective are the student-driven environmental programs across UC, CSU, and higher education institutions nation-wide?** Are there metrics that could reliably "benchmark" these programs' overall performance and comparative effectiveness? Do these programs modify students' personal behaviors? Is this impact widespread or limited to a few core "believers"? How long do behavioral changes persist? Are students who participate in these programs more likely to become future leaders?

39. **Do students who attend LEED-certified schools perform better, or do patients treated in sustainably-designed and built hospitals experience shorter recoveries?** Such claims cite data that do not look beyond simple explanations to consider possible multivariate factors. For example, the major drivers behind the metric "average hospital stay" are the acuity of the patient base and the mix of services, closely followed by the economic status of the patient population. Thus, a hospital that provides few risky services to an affluent patient base will report shorter average length of stay than an urban academic medical center with a trauma service and cancer center treating acutely ill patients. A LEED-equivalent hospital room *may* speed patient recovery time, but any

such correlation would need to control for potentially confounding variables, as well as possibly hidden covariant factors. An evaluation of whether students learn better in green schools would similarly need to control for other factors that could explain observed variance, including possible socioeconomic factors. Similarly, the assertion that people who work in green offices experience fewer sick days would require a multivariate study. It is important to verify green building causality hypotheses with rigor, rather than rely on broad claims that could discredit LEED if later disproven.

40. **Assess the opportunity for UC Irvine to develop a Sustainable Community Program with the City of Irvine.** Examine existing and emerging UC Irvine and City of Irvine environmental programs. Are there University programs that could be expanded to a community level, or vice-versa? Would joint programming be a difficult convergence of disparate agendas or an easy symbiosis of common interests?

41. **Would energy metering and reporting down to the department level lead to greater awareness, accountability, and motivation to reduce energy use on campus?** Conduct a pilot project in cooperation with one or more campus departments, meter their energy usage, and provide them with a monthly assessment of their energy usage, the cost of such usage, and suggested actions they can take to save energy and reduce carbon emissions.

42. **What percentage of U.S. energy supply can be projected from renewables by 2020, based on an apolitical analysis and realistic premises?** Critics of renewable energy claim that, at best, only a minute fraction of the nation's growing energy needs will be met by renewable energy; that more optimistic projections are tainted by "political correctness," lack of scientific rigor, vested interests of proponents, and government subsidies that obscure the economic infeasibility of many renewables; and that resources should more productively be channeled into coal gasification, carbon sequestration, breeder reactors, and other derivatives of traditional fuels and technologies. The opposite view holds that technology price/performance breakthroughs in such areas as photovoltaics or bio-engineered fuels are not included in skeptics' projections; that other forms of solar power collection may outperform photovoltaics in large-scale facilities; that renewable technologies such as tidal and wave energy, wastestream incineration, wind farms, and enhanced geothermal systems are not sufficiently recognized; and that government support will favor development of renewable technologies if dollars per unit of reduced carbon emissions is the yardstick applied. A realistic, objective, non-politicized, and comprehensive assessment is needed -- one that takes into account in a neutral, rigorous way the views of skeptics as well as proponents on both sides of this debate. Such an assessment should evaluate what is realistic to expect in the way of technological and price/performance improvements for both renewable technologies as well as technologies that stem from traditional forms of energy and the future economics of developing marginal reserves -- whether oil shale or marginal lands to produce more bio-fuel -- need to be factored into a complete analysis. Of course, certain assumptions

will need to be made about government incentives and regulation, economic and market dynamics, and consumer and voter behavior. In such an analysis, increased efficiency should not be included as "renewable" (although it is surely "green"), inasmuch as efficiency gains will apply regardless of the ultimate constellation of energy sources. Finally, it is important to emphasize that the point of this study is not to affirm or "disprove" a particular view of renewables' future, but rather to derive an informed, nuanced understanding based on solid analysis.

43. **Determine whether any campus locations where closely-spaced buildings form a barrier to prevailing winds could support a small wind generator**. A feasible location will have the wind speed and consistency, as well as installation conditions, to support a financeable investment.

44. **Based on study of past changes in attitudes and awareness about natural resources, how does consciousness change from faith in unlimited natural resources to awareness of finite limits -- from robust to fragile**? What can be learned from other cultures about how collective attitudes and shared values around environmental stewardship take shape and evolve over time? Does it require a crisis to create a large shift in values, or a price shock, or a war, or a health scare? Do less acute processes such as education or religion change consciousness about natural resource problems? How does a resource that was once viewed as more than ample, such as the atmosphere, change from appearing “free” to finite, and thus more valuable, in people’s perception? What factors determine whether a recognized natural resource problem is viewed as government’s responsibility to solve vs. individuals’ collective responsibility as citizens? What experiences and lessons extend people’s view of value beyond pecuniary prices and costs, to recognition of externalities and noneconomic costs and benefits? And what changes values about whether individuals should be held accountable for environmental externalities of their activities that went unaccounted in the past? Finally, will individuals respond to the concept of a “personal carbon footprint” to a degree that sharply changes their behavior, or will the costs of carbon emissions and other natural resource externalities need to be structured into a price system in order to sufficiently change behavior?

45. **What combination of prices, discounts, or incentives as well as convenient alternatives will convince residential students to forego having a car on campus?** The true economic value of parking approaches $150 per month. (Such a figure takes into account the value of land and the opportunity cost of using land inefficiently for surface parking, or the alternative cost of more density somewhere on campus if parking consumes land inefficiently.) This price differential can be applied through a separate charge for residential parking or a discount for residents who elect not to store a car on campus. In addition to a substantial price or discount incentive, what other services would be necessary to induce a large percentage of students to forego a car on campus? Would a convenient “flex car,” by-the-hour rental program help achieve the result?

Would shuttle bus service to shopping make a difference? Would convenient access to particular retail services on or near campus be a factor?

46. **How much peak power capacity could be achieved in California by requiring all swimming pools to install power interrupters that could be activated State-wide when necessary for peak-shaving?** California has tens of thousands, if not hundreds of thousands, of private and public swimming pools with multi-horsepower circulation pumps. Public pools are required by a California health regulation to circulate and filtrate water constantly when the pool is in use, although it is not clear that a pool would build up bacteria to an unsafe level during minutes or even hours of outage. (Water treatment, not filtration, is what makes a pool hygienic.) In evaluating State-wide energy consumed by swimming pools, also consider the carbon savings if fossil fuel-heated pools were required to have insulated covers.

47. **Where do people learn, or unlearn, beliefs that cause them to resist changing their behavior for the sake of environmental benefit?** Is education the root of resistance or of new insight? For example, the view that nature is limitless and natural resources abundant can be found in elementary school materials. Do religious views play a role -- e.g., God provided natural resources for humans' use and Nature's self-regulating stasis will intervene before resource problems reach catastrophic proportions? Do political attitudes play a role, to the effect that difficult problems are easier to defer until someone else can be blamed for both the problem and the cost? Does the prevalent political philosophy assume that a combination of economic market incentives and technology will converge on a solution? Or do people tend to withhold their belief in scientific explanations until there are no dissenting views?

48. **Is intentionally limiting parking supply an environmental impact or an environmental benefit?** Two of the most prominent environmental programs implemented on California campuses, LEED (US Green Building Council's Leadership in Energy and Environmental Design program) and CEQA (California Environmental Quality Act), take an opposite approach to parking supply. LEED awards credit points for *under*-building parking supply below municipal standards, while CEQA determines that the identical practice is an "adverse environmental impact." In considering direct effects (trip reduction, air quality) as well as secondary effects (e.g., foraging for parking spaces, parking overflow into local communities), is the LEED approach or the CEQA approach more valid?

49. **Public health vs. clean water -- balancing the greater public good.** Current practice for implementing the United States Clean Water Act (e.g., NPDES) involves utilizing bioswales, filtration marshes, retention basins, percolation basins, and other similar features to clean first flush and low-flow water runoff before entering waterways. Do these features conflict with public health goals to limit shallow, vegetated areas of

standing water in support of vector control for West Nile virus and other mosquito-borne public health threats?

50. **What combination of factors would be required in order to reduce UCI trip generation by 25 percent without compromising UCI's strategic academic objectives?** Reduction of campus daily off-campus trip generation by 25 percent would require significant changes in parking policy, alternative transportation programs, delivery of education, and lifestyle. Some would argue that these constraints go too far, keeping faculty and visitors away from the campus and placing UC Irvine at a disadvantage compared to other leading institutions where convenient parking is amply provided (although all universities will be pursuing parking demand alternatives to some degree). What combination of policies and actions would optimize trip reduction as well as achievement of campus desirability and community living standards?

51. **Can the ASUCI shuttle system be expanded to serve the greater Irvine community as an element of an integrated Irvine community public transit system?** UCI and the City of Irvine share common interests regarding public transit. Irvine's plans include operation of three public transit systems serving the City. Can the ASUCI shuttle system be expanded to function as the fourth leg of this system by serving both campus affiliates and the general public? What funding, policy, and transportation planning issues pertain to such a proposal?

52. **Can University Hills housing be built out at a higher density than currently planned in the campus' Long Range Development Plan?** University Hills provides ownership housing primarily for full-time, ladder faculty, although many people have pointed out the desirability of providing affordable housing for more non-ladder faculty, postdoctoral fellows, and academic and nonacademic staff. The campus' Long Range Development Plan increases student housing density 50 percent, to 90 bed spaces per acre, in order to allocate more land to faculty housing, which is planned at 12.5 dwelling units (households) per acre -- a mix of attached and detached units. University Hills homes have similar features compared to modern real estate products. American homes are 40 percent larger, on average, than thirty years ago, many with seldom-used living rooms *and* generous family rooms, entries that constitute entire rooms, dining rooms that get used only on special occasions (in addition to everyday eating areas), multi-car garages, fireplaces (which, although seldom used and gas log-equipped, are of dubious "green" merit), walk-in closets as large as children's bedrooms used to be, and almost as many bathrooms as bedrooms -- many with tubs that are never used. University Hills homes are somewhat more land-efficient than other modern real estate products; for example, since many University Hills residents walk or bike to their offices, the average number of garage spaces per unit is reduced. Nonetheless, there may be an opportunity to develop an exemplary, "green" product that is more land-efficient, that is more vertically compact, and that includes such features as solar hot water, photovoltaics, and reclaimed water for toilets and landscape irrigation.

53. **Which is better for the environment -- the cotton shirt, the silk shirt, or the polyester shirt? Or, for your new hybrid car, should you order the leather, vinyl, or fabric upholstery?** The answers may not be as obvious as it seems. Consider all factors, cradle to grave life-cycle, care impacts as well as creation and disposal, impact on all natural resource systems, carbon emissions effects, length of service life, etc.

54. **Evaluate whether UC Irvine's "hospitality practices" could be greener without compromising hospitality objectives.** At many UC Irvine events one finds party favors or "gift boxes" at one's place setting. Regrettably, many of these hospitality gifts end up in the landfill. A worthwhile project would work with campus event planners to develop guidelines for "greener" party favors and conference packets, if such gifts and souvenirs are considered an essential part of the experience we want to create for campus guests.

55. **Evaluate the role of easy credit, multiple wage-earner family units, home improvement television programs, and "home and garden" magazines in fueling non-green housing trends**, including escalating home sizes; more use of exotic plant materials for landscaping; materials mined and shipped from distant places; the need to "update" kitchen and bathroom finishes, fixtures, and appliances if they are more than ten years "out-dated"; high volume spaces for seldom used rooms such as entries and living rooms; furniture styles that go out of style long before the useful life ends; and numerous other home amenities, features, and trends that are increasingly taken for granted without regard to environmental impacts. In addition, consider whether any of the information and marketing tools that have helped foster environmentally adverse homeowner trends can be realigned to influence consumer behavior in the *opposite* direction -- toward renovation that is "greener" and less fashion-driven, and toward new construction that requires a smaller carbon footprint.

56. **Develop a business model for an airline that creates a smaller carbon footprint using current technology to deliver an unchanged number of passenger-miles with no net reduction in passenger travel time.** Consider whether the energy, carbon emissions, and dollar savings of reducing airspeed can be counterbalanced by speedier gate turnarounds, faster passenger loading and unloading using front and rear doors, push-back while engines are being started (with quick disconnect), less passenger utilization of carry-on luggage by improving baggage claim service -- with the net result that in-flight intervals would lengthen somewhat but the time passengers have to stand in line loading, waiting for the final passengers to load, and waiting for luggage would entirely compensate for slower cruising speeds. Evaluate whether such a tradeoff is operationally feasible and whether the added costs for double ramps, improved luggage services, and other gate services necessary to counter-balance time impacts on customers can be financed by fuel savings, including reduced fuel loads. Finally, convince a progressive airline to test this business model.

57. **Will barriers to sharing technology limit international cooperation in reducing carbon emissions?** Economic incentives and foreign policy barriers limit international sharing of many forms of new technology. When it comes to reducing carbon emissions, will the perception of "a common enemy" lower barriers to international technological cooperation? Does history provide any parallels that might illuminate this question -- eras when a perceived massive, common threat increased international collaboration and eclipsed conflicts and differences? Does global warming represent a potential opportunity to focus on common interests with regimes with whom we do not currently share many foreign policy interests?

58. **Could a California-wide consumer electric load-leveling policy (enacted through a combination of incentives and regulations) reduce carbon emissions?** Since peak power generators are less carbon-efficient than base-load generators, should the State require all large consumers of air conditioning -- e.g., installations using more than 5,000 ton-hours of cooling per day -- to invest in thermal energy storage? Are there other State-wide measures that would substantially help to flatten California's load profile -- for example, requiring all private and public swimming pool filtration pumps to run off-peak? Are regulations or added incentives needed (beyond existing time-of-use pricing differentials) to induce large power purchasers to flatten their load profiles?

59. **How will consumer goods manufacturers react if/when consumer attitudes shift away from buying more and newer goods that are ostensibly "green" toward less materialistic consumption per se, with less emphasis on trends and fashions and more value on durability and repair-ability?** Or, is such a shift in consumer attitudes unlikely to occur in developed economies? Will the corollary of the "buy less stuff" motto become "buy longer-lasting stuff"? What forces or influences could change values in a consumer-driven society that now equates "living better" with buying power? Will people's values change at a fundamental level, or will their values evolve alongside changes in buying behavior as carbon costs and other resource externalities are built into the *prices* that consumers pay? If the latter dynamic is predicted, is there a case for allocating all such costs in a way that affects the specific prices that consumers experience rather than decoupling costs by absorbing them into generalized tax or pricing structures?

60. **In order to achieve California carbon-neutral goals, should the State require secondary schools to charge for parking and to earmark the revenues to subsidize alternatives for students willing to forego driving?** By the time many California students matriculate to college, they have become automobile-dependent, which makes it difficult to entice students to use transportation alternatives. What would be the impact on traffic, modes of transportation, carbon emissions, traffic infrastructure requirements, and future transportation habits when high school students matriculate to college if high

schools charged an amount reflecting full economic value for parking permits (including land value) and used the revenues to pay for free bus passes (which could, in turn, leverage improved bus service) as well as better bicycle and electric scooter facilities? Could the savings in traffic infrastructure somehow be channeled into the schools as an added incentive (perhaps by relieving secondary schools of the obligation to pay for capital improvements in roads and intersections when fewer traffic mitigations are ultimately needed)?

61. **Can a market system provide enough emissions credits to meet the aggregate demands of all government entities, institutions, and corporations that have adopted carbon-neutral goals?** Most carbon-neutral plans (including emerging draft plans) project a modest improvement in efficiency and associated emissions, a slight reduction stemming from behavioral changes, perhaps a modest installation of renewable energy, and a *massive* procurement of emissions credits to bridge the remaining gap that needs to be closed in order to reach carbon-neutrality. The pattern of hinging "climate action plans" primarily on purchased emissions credits is already apparent. However, whether a market system can provide emissions credits at the scale needed to address these aggregate plans warrants a serious analysis. Climate-neutral plans also tend to assume that emissions credits will be procurable at feasible prices -- an assumption that also calls for analysis.

62. **What is the total, comparative carbon footprint of a take-out dinner compared to a home-cooked dinner?** Consider all the factors including transportation, space utilization, water, and waste as well as direct energy consumption.

63. **Analyze your grandparents' carbon footprint in comparison with your parents' carbon footprint.** Using a personal greenhouse gas footprint calculator, compare their respective households and living patterns in (for example) 1960 and 1990. Include shopping, consumption, recreation, travel, home remodeling, eating-out, food sourcing and storage, space utilization, recycling, and disposal practices as well as direct energy usage patterns, fuel sources, and energy-efficiencies. Interview your parents and grandparents in order to use informed estimates for home sizes, transportation modes, miles and miles-per-gallon, weekly shopping, imported products and foods, clothes-washing, dishwashing, and all the "modern conveniences" in your parents' home. Identify the elements of your parents' carbon footprint that were smaller than your grandparents', if any. Determine whether the "footprint calculator" you are using omits significant greenhouse gases and/or overlooks personal behaviors that produce greenhouse gases, and work with the author to improve the model, as needed. Finally, determine what elements of your parents' carbon footprint you would like to reduce in your own life, and whether you can reduce these back to the level of your grandparents' carbon footprint.

64. **Determine what percentage of Southern California commuting could be accomplished, with what net savings in carbon emissions, if an affordable plug-in hybrid car with a 40-mile range were marketed.** Defend the reasonableness of your assumptions, which will have a critical impact on your projections.

65. **Should you rinse out and recycle that plastic container, or throw it in the trash?** Does the "correct" answer differ if water *and* carbon are considered rather than water consumption *or* carbon emissions? Does the conclusion vary based on whether the container is aluminum, tin, plastic, glass, or paper/cardboard?

66. **Modify flush valves to reduce water consumption without incurring the cost of replacement.** Many urinal flush valves (and some water closet flush valves) are in low-use environments that do not warrant the investment in valve replacement, yet these valves permit a flow-interval that far exceeds the volume required to clear the bowl. Some of these valves are electrical and some are mechanical. This assignment involves designing a low-cost retrofit to existing flush valves (at a cost that is less than one-third that of valve replacement) that will reduce the flow volume to the minimum quantity that will clear waste. This requires a multi-faceted solution that will work on several brands and models of flush valves, with sufficient variation, tolerance, or adjustability to accommodate a range of water pressures at the point of application. The solution must meet robust, institutional engineering quality standards for long term, trouble-free usage.

67. **Based on projected price/performance improvements, does it make sense to invest now in renewable energy projects, or is it more sensible to wait?** This question calls for an investment model that carefully considers cost of capital (which may vary for public vs. private investors, or for institutional vs. commercial investors); projected net present value (for which the assumptions may vary among the different types of investors noted above and thus yield different "answers"); projected rates of technological and "know how" price/performance improvements; and anticipated subsidies and tax breaks, including an evaluation of whether such incentives may *slow down* technological advances -- a significant research topic, in itself. The question of now vs. later is far from theoretical. Rather, this decision confronts every CFO of every business enterprise and institution with a commitment to reduce their "carbon footprint." A multifaceted model is required that evaluates differentially the various renewable energy choices. One distinct alternative that warrants evaluation for an entity under a mandate to attain a certain "green" power percentage and timetable is to procure renewable power from a utility until on-site renewable energy investments reach a more favorable balance between price, performance, and feasibility.

68. **Will carbon-neutrality ultimately prove too difficult and daunting, to a degree that leads to disillusionment and abandonment of this goal?** Would carbon-*efficient* goals for roll-backs to prior decades' carbon emission benchmarks, rather than complete negation, prove more motivating due to greater feasibility? Does carbon-neutrality even

make sense as a policy goal, in that most businesses and institutions will have to resort to emissions credits that will, in effect, *offset an increasing output* of carbon emissions rather than yield net reductions in atmospheric emissions?

69. **Will a sustainable dining program result in healthier diners?** Compare the average caloric, fat, and other nutritional metrics of a sustainable dining program with the prior program or with a parallel program serving a similar population. Are people eating healthier and more sensibly? If so, is it because the sustainable dining program has eliminated unhealthy menu choices, or because healthier dining choices are being made by individuals based on better information? Do sustainable dining and improved health correlate, or do some healthy menu attributes differ from the menu that would result solely from making the dining program sustainable?

70. **Can a sustainable dining program pay for itself through reduction of waste?** Locally-sourced and sustainably produced food does entail a price premium. However, cafeteria dining programs typically generate considerable waste. Can portion "right-sizing," tray-less dining, and customer awareness yield savings sufficient to actually accommodate cost pressures without resorting to price increases? Looking decades ahead, will healthier dining yield downstream benefits in the *future* lives of cafeteria users? Can the current and long-term benefits and costs be demonstrated in a rigorous life-cycle cost model?

71. **Design a solar-powered vertical shade for conventional windows in offices, laboratories, and other workplace environments that makes daylight harvesting more effective.** There is a problem with "daylight harvesting" from west-, south-, and east-facing windows, regardless of whether the strategy employed is daylight sensors on lighting fixtures near windows or manual-on/auto-off occupancy sensor switching for such fixtures: When users close blinds to control direct sun, the shades tend to remain closed. A shading device is needed that is "smart" enough to keep vertical shades normal to the planar angle of incident sun, fully open to maximize daylighting when no direct sun will enter, and closed during nighttime hours for both privacy and increased thermal performance. Such a "smart shade" will even benefit north-facing windows, where shades need to be closed at night but fully opened during daylight hours.

72. **What is the best long-term replacement for campus bio-diesel shuttle buses?** Eventually the campus' fleet of retrofitted bio-diesel buses will require replacement, and if bio-diesel fuel creates environmental problems rather than ameliorating an environmental problem (re-use of waste cooking oil), another carbon-neutral solution will surely be sought. However, investing in a replacement fleet will be costly, and cost-feasibility will need to be weighed against carbon-efficiency, factoring in students' willingness to pay for an environmentally robust, carbon-neutral solution. Another factor in such an evaluation is that a phased investment in a renewed shuttle bus fleet will probably be required; the fleet is too expensive to replace overnight. And a system

that requires an expensive, new fueling infrastructure may prove infeasible from a phased funding standpoint.

73. **What types of regulations will be required to prevent a future scandal in the market for emissions credits?** As emissions credits become marketed, "commoditized," and more expensive and sought after, the potential for exploitative economic behaviors will heighten. Some early evidence already exists in this regard: At a recent national conference, a speaker mentioned a renewable energy consortium that is "selling both the emissions credits and the carbon credits." This belies either a basic definitional problem or opportunistic multiple-selling of an unverifiable "benefit." In an unregulated market with sharply rising demand but no agreed-upon definitions, authentication standards, or verification criteria, the seeds of a confidence-eroding scandal seem evident.

74. **Will value-based and information-based forms of influence lead to compromises in people's "standard of living" expectations, or will full pricing of atmospheric externalities be necessary to actually change what is regarded as a deserved standard of living?** Television is replete with programs on "green renovation projects" and 5,000 square foot "green" vacation homes on generous, remote sites. Few people have faced the possibility that the presumed standard of living to which educated people aspire may actually have to *change*. Has any society gone through a transformation away from consumer consumption, with the latest and most modern new technology, distant vacations, air conditioned comfort, new cars, and the best leisure activities affordable, and *toward* values that equate a standard of living with intentional resourcefulness, quality rather than quantity, "styles" that last decades rather than months, aesthetics rather than bold gestures, leisure activities that are low-impact, less and slower mobility, and fixing salvageable goods rather than discarding and "updating" with the newest trends? Can such values actually take root, apart from a small group of ardent environmentalists, or will values follow where economics dictate once the full cost of atmospheric externalities are fully reflected in prices and investments?

75. **If less consumer consumption occurs in developed countries due to greening societal values or simply because of prices that include environmental externalities, how will lifestyles change in terms of activities that displace shopping and eating out?** Will the performing and visual arts flourish? Will healthier lifestyles emerge? Will people actually start to cook at home in their upscale kitchens? Will any of the more carbon-efficient lifestyles of, say, fifty years ago return -- or is such thinking delusional?

76. **Do the federal hybrid car incentive quotas make sense as currently structured?** For example, now that the most carbon-efficient hybrid model has exhausted its tax credit quota, consumers have an incentive to purchase less efficient hybrids that, in some cases, do not even outperform non-hybrid automobiles. If tax incentives stimulate demand, is

the net effect higher prices, thus bestowing the tax benefit on manufacturers more than consumers? Or, if the net effect of tax credits for hybrids is to reward manufacturers who produce hybrids, does it make sense to provide a tax incentive for a 330 horsepower, three ton SUV hybrid? Most tax incentive programs designed to channel consumer behavior into desired alternatives can be criticized for *some* inherent inefficiencies or irrationalities, but is the federal program of tax credits for hybrids worse than most such programs in terms of its policy efficacy?

77. **Determine the greenhouse gas impact of one person's yearly consumption of bottled water.** Determine how much water is used in the processing plant per unit of production, and include the comparative inherent energy content, transportation and delivery impacts, packaging and disposal (or container recycling) impacts, sunk costs associated with the investment in a water distribution system that is not being fully utilized for drinking water, and the impacts to agriculture (and resultant greenhouse emissions effects, if any) if processed water products consume more water resources than utility-distributed water. Finally, factor in the user tendency to refrigerate bottled water.

78. **With earlier snowmelt patterns changing watersheds and the timing of water resources, would it make sense to re-think the role of dams?** If global warming results in earlier snowmelts, what are the downstream, seasonal effects on rivers, reservoirs, hydroelectric facilities, wildlife, streambed plants, and water resources? With snowpack-fed streams running low or draining dry earlier, would dams be an alternative way to moderate flow rates, store water that used to be stored as snowpack, and generate carbon-neutral power in a way that could address several problems concurrently? Do these multiple benefits change the balance of interests that currently weight against large hydro projects, especially given that hydronic patterns are changing regardless, with earlier snow melts? Is there a river management program that could address biotic concerns in an efficacious way while managing water resources and yielding carbon-neutral power -- in effect, managing all of these problems in an environmentally sensible manner? Is the appropriate baseline against which to judge environmental efficacy current flow conditions or projected flow conditions (which may make the prospect of built structures that moderate flow more desirable if habitat conditions are destined to change regardless).

79. **Assuming that you cannot use a clothesline today, should you set the clothes drier at the highest or the lowest heat setting?** At what point does the difference in exhausted heat exceed the additional motor energy associated with a longer drying interval? Does the answer differ if the clothes drier uses electric heat rather than natural gas heat?

80. **Which action creates the smaller carbon footprint: Going shopping or ordering via the Internet?** The answer requires a complete carbon inventory of every step, every

movement, every packaging material, and every space involved in the two processes being compared. And, of course, the answer may differ depending on whether you drive alone, carpool, consolidate trips, or take the bus to your shopping destination, and perhaps depending on what shipping option you select for your internet order. Don't forget to factor into the carbon footprint an increment for shipping the fraction of goods that needs to be returned for reasons that would have been avoided by an in-person purchase.

81. **What ultimate price of wind energy carbon emissions credits will reflect not only the incremental investment and net operating expense of the generating machines but also the cost of distributing the power to load centers where it will realistically displace high-carbon generation?** In order for a wind generator to mitigate carbon (and hence qualify for a subsidy in the form of a purchased emissions credit), it needs to displace a carbon-producing form of generation -- preferably a high-carbon generator. This requires transmitting the power (and accounting for transmission losses) to a load that is currently served by such generation, and creating a cost advantage favoring the renewable option through subsidization. These factors, properly accounted for, affect the ultimate cost of emissions credits if wind power is the presumed most cost-effective renewable alternative. It would be useful for institutions and corporations to understand a projection of this ultimate cost if their climate-neutral plans depend on procurement of emissions credits for the part of their carbon footprint that cannot be mitigated through operating savings or on-site renewable power.

82. **Will biomass projects be undermined by rising costs for biomass fuel sources as more projects induce higher prices?** Many institutions and renewable energy companies are currently favoring biomass projects due to their favorable economic parameters. Will increasing demand raise biomass prices to a degree that will undermine the financial stability of existing projects, or the financial feasibility of planned and future projects? Based on economic theory, can an eventual price be projected for biomass – as a relative percentage of an established commodity such as natural gas, if not on an absolute basis? At such an equilibrium price, will most, few, or no biomass generation projects be feasible (and to what extent will factors such as fuel proximity and project scale become more important)?

83. **If regulated non-greenhouse emissions can be reduced for plasma gasification or incineration technologies to an extent that equals that of biomass digestion in combination with combustion, would these direct conversion technologies outperform digestion/combustion in terms of costs vs. benefits and energy harvested per unit of greenhouse gas emissions?** Will a clear "winner" emerge among these technologies, or will the best choice depend on conditions such as the type of biomass, scale of the facility, local environmental regulations, facility appearance, operating expense and technical expertise requirements, and the like?

84. **What necessary data attributes about carbon-generating behaviors lead to individuals' changing their behavior?** The Toyota Prius has an exemplary data display that causes drivers to consciously alter their driving behavior. On the other hand, for years drivers have had a fuel gauge to provide feedback on their driving behavior, but with limited effect (other than to trigger the behavior of re-fueling). Some buildings display real-time energy consumption (which could be equated to carbon emissions) but the impact on occupants' behaviors has been disappointing. So do data displays need to provide the device-specific, individual-user, real-time + recent history + longer history, and graphic display attributes of the Prius, or would the daily (more aggregated and thus averaged) energy or carbon metrics for a group, laboratory, or floor of a building create behavioral results? And what should be measured -- the rate of expenditure, of energy consumed, or of carbon generated in the case of a building, room, lab, or device? What are the key data attributes in terms of timing, averaging, aggregation or disaggregation, units of measure, and display features that lead to behavioral influence at the individual or group levels? It is important to understand data attributes that will prove successful before investing in numerous sensors and data displays that may not prove effective in changing carbon-generating behavior.