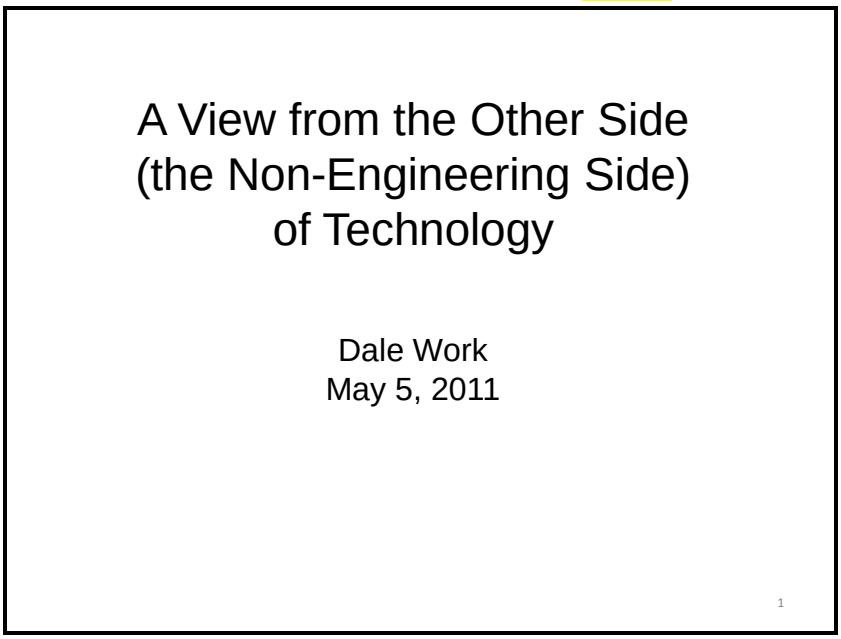
A View from the Other Side (the Non-Engineering side) of Technology

Slide 1

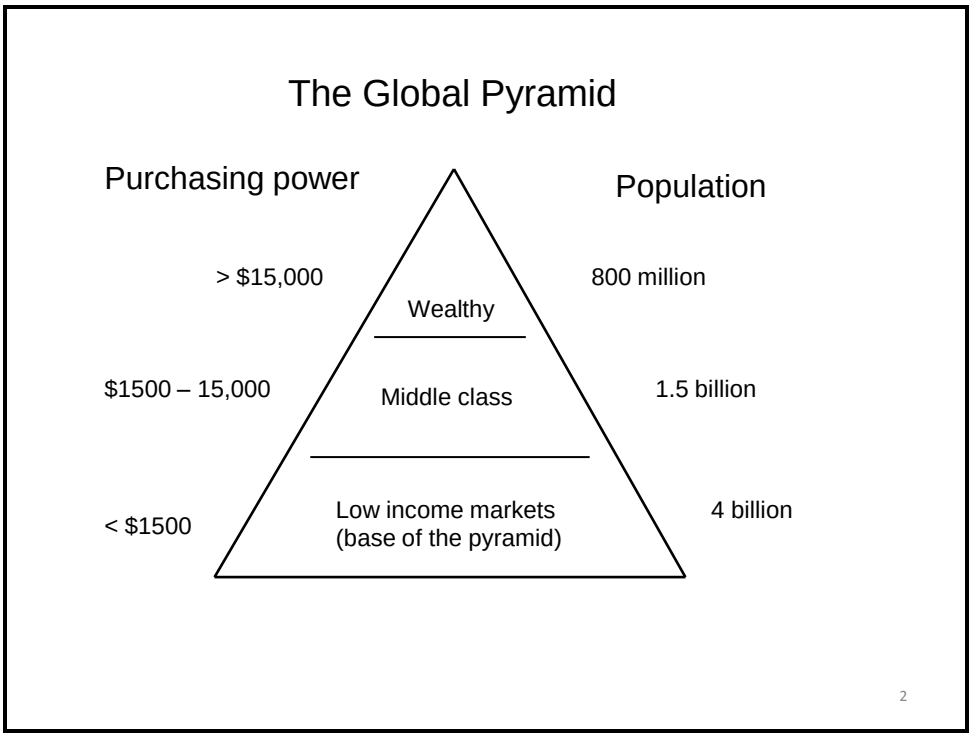


Tonight's talk is about dreaming. I'll ask a lot of questions in an effort to challenge our thinking, and while I may not be able to answer them, we can at least think about possible answers together. We can dream together.

Technology is important. But in a commercial sense, it is not as important as many in this room would like to think. I once thought that technological leadership was the key to growing profitability; I no longer believe that. Of course, all of our products have a strong technical foundation, and without measurement standards we could not engage in robust commerce. Yet, my belief is that technologists over-rely on engineering judgments in their attempts to shape our future. Our world is not comprised chiefly of engineers – not our politicians, possibly not even the top decision makers in your companies, and certainly not most consumers of our products. What may seem reasonable and even compelling to engineers and scientists may not be convincing at all to others. Surely you have had this experience, when you wonder how our political leaders make the decisions they do. You may have even had this same sense of surprise in your own company. Why is this? What are we as engineers missing? Do our expectations need adjusting? As technologists, we need more dreaming, and less reliance on rational engineering thinking. Tonight, we'll look at technology from a non-engineering perspective.

Outline of talk: first the lighting world we live in, then the world as it can be, and how SSL can fit into that new world. What is, and what should be, the role of technologists in this new world? Suggest a way that metrologists can contribute to making this a better lighting world. Near the end I will digress to talk about the "Light Bulb Law" currently being discussed in Congress.

Today's lamp world is global. In the 1970s, there were 3 major lamp companies in the U.S. [General Electric, Westinghouse, and GTE Sylvania], and there were 3 in Europe [Philips, Osram, and Thorn]. Since then General Electric has bought Thorn, Philips has bought Westinghouse, and Osram has bought Sylvania, so that today there are 3 major global players with about 60% of the market. All 3 of these companies, to the best of my knowledge, target only the wealthiest people on earth as their customers. [Slide 2]



Here is a profile of the world according to wealth and population. Nearly all major lighting companies target the top level of this pyramid, the wealthiest 13% of people. By far, most of their development and commercial activity is directed toward this top level, with some attention to the middle level. I think this is true for the western world and for Japan as well. The bottom of the pyramid can't afford to shop much for lighting, and 40% of these people do not have access to grid electricity anyway.

[Slide 3]

Lighting energy use (in %) [U.S. - world]

	inc	fluor	HID	light (%) [lm-hrs]
Residential	-	-	-	10 14
Commercial	-	-	-	56 45
Industrial	-	-	-	21 29
Outdoor	-	-	-	13 12
energy (%)	42	41	17	100
light (%)	12 11	62 62	26 27	100 100

3

shows that the world is rather similar in its use of lighting. Looking at the different lighting technologies, the columns, there is hardly any difference between the U.S. and the world, and in terms of applications, the rows, there are some differences but the overall picture is similar. Incandescent lamps consume over 40% of lighting energy and generate only about 12% of our light (lumen-hours). Fluorescent lamps also consume about 40% of the energy used for lighting, but deliver over 60% of our electric light. What that means in the U.S. is that the equivalent of 40 large power plants (that is, giant, nuclear-sized, gigawatt ones) are used to power nothing but incandescent lamps.

Why hasn't the world completely switched over from incandescent to fluorescent lighting? It has certainly had time. It would have saved a lot of energy and a lot of money. Each was a disruptive technology when introduced, just as SSL is today. Engineers have given them the measurement standards they need to make an informed purchasing decision. Then why hasn't the world switched? Why haven't you switched? These are questions with implications for Solid State Lighting.

Here's a related question: why has Japan long ago switched to fluorescent lighting to a far greater extent than the West? Why should one region of the world behave so differently from another? All regions have the same laws of physics and the same broad lighting technologies. Could it be that technology is not the reason for the different behaviors? Is style or fashion or custom or culture at least as important as technology? Will that be true going forward?

In the West, we share a striking under-use of energy efficient lighting products. About 5 years ago, Philips estimated that in Europe, about 3/4 of installed lighting used older less efficient

technologies when more efficient ones were available and had been available for several years. What do we make of this reluctance to adopt new, improved, money-saving technologies? I offer three observations.

> First, it appears that technology has not failed. New products have been developed, and you can't blame the engineers if the public doesn't embrace these new technologies. But have technologists done their job as well as they should have? Is the engineer's job done when products are developed, specified, and placed in the warehouse? Do we have any responsibility to accelerate the public's adoption of these new technologies?
>
> A second observation. It seems that our customers often do not focus on the total cost of ownership when making lighting decisions, as irrational as that may seem to engineers. But wait: I suspect that this is true not only for the public in general, but for most of us in this room as well. Is this a surprise?
>
> Third, there seems to be a huge gap in lighting education that is difficult to fill. Lighting is not a high interest category, and we use hard-to-communicate, non-intuitive metrics and jargon: efficacy, CRI, CCT. What does all of this mean for the adoption of SSL?

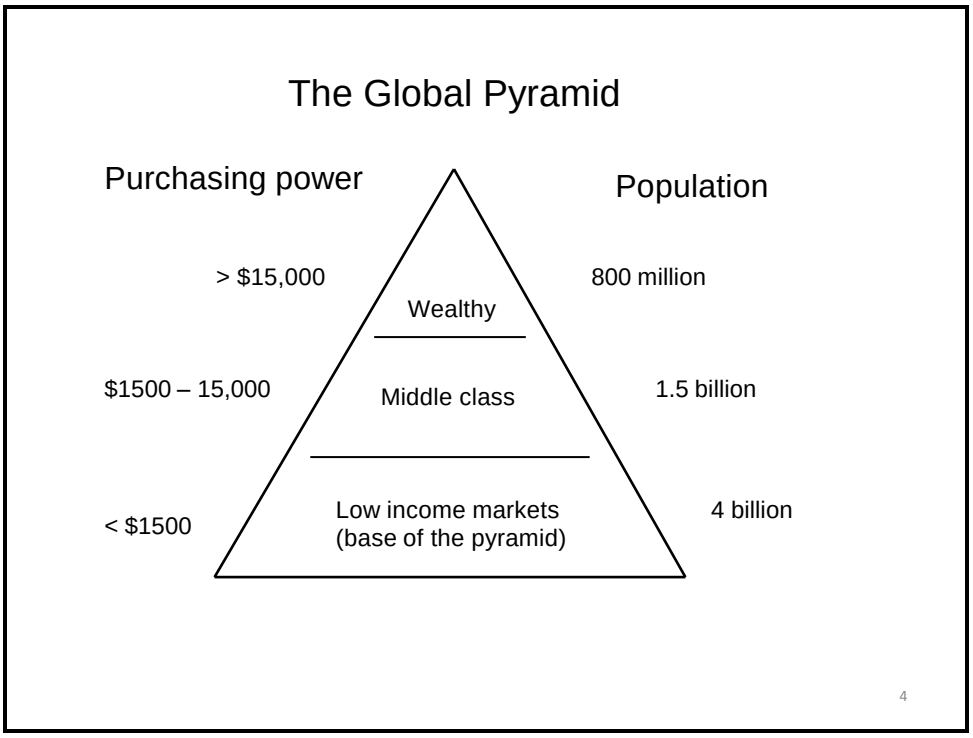
A central question: Is our lighting world a rational one? Is it rational for people, even very cost conscious people, to spend more for lighting than they have to in order to get good lighting? I think the answer is "yes" – people behave in a way that makes sense to them, based on the information they have, and based on their understanding of that information. The fact that their choice does not seem rational to us doesn't mean it isn't rational to them. The fact that our marketing departments may see the world differently is irrelevant. Could we engineers have described our products in some different and better way that would have lowered the barrier to changed consumer behavior? Have we made any attempt to do so? Do we need metrics that make the explanation of product features much more understandable? Will this same "reluctance to change" be true for SSL as well? Is SSL really destined to take over the lighting world, as many people say, or will it find unexpected barriers? Will there be a CORM talk 30 years from tonight asking why the market hasn't embraced the new SSL technology, as was projected in 2011?

This is the lighting world we live in. What about the lighting world of the future?

Let's start with the earlier question: why will people convert to SSL in the future if they haven't converted to efficient products in the past? Unless something changes, we can assume that people will continue to choose less efficient systems over more efficient ones. Einstein is usually credited with this definition of "insanity: doing the same thing over and over again and expecting different results." We can safely apply this definition to the projected take-over by SSL unless we do something different. What can break this pattern of very slow adoption of

new, more efficient technologies? I suggest that there are two ways that this pattern can be broken: (1) by finding new markets where there is no established practice to serve as a barrier, and (2) by purposeful government intervention. Today these are only dreams.

1. First, one reason why the world going forward can be much different than today's world for SSL is that this LED technology is well suited to address market segments that today are ignored. [Slide 3 again]



For the bottom of the pyramid, and for the middle of the pyramid, SSL has possibilities that traditional lighting products do not. SSL lighting can be a status purchase, and not just a necessity. Even where low cost is the paramount concern, new SSL systems can offer affordable lighting possibilities at performance levels appropriate to this relatively primitive market. Further, the bottom of the pyramid infrastructure is not dominated by "incandescent" thinking and incandescent hardware. There are no retrofit constraints to be managed.

Solid state lighting can be attractive in all 3 levels of the pyramid. But industry will have to target market segments, even pyramid segments, that haven't been addressed before. What are the implications for measurements and standards? Does CORM ever address this, or dream along this line? Do measurement standards have to respond to the market, after the fact, or can they also lead the way to open up marketing possibilities where none exist today? I think this will happen during the lifetime of some of the younger people in this room. It will be a world that belongs to dreamers. A bias toward measurements is inappropriate when applied to the future. We need to set aside time for dreaming in our

companies, and in our conferences.

2. More government involvement is possible and desirable. Better lighting quality with financial and environmental benefits and with no degradation in lighting performance is a suitable subject for public policy. This position may not be widely shared by CORM conference participants.

   The government's role in implementing lighting public policy that benefits everyone has been too long underappreciated. The results can be a win for consumers, a win for the environment, a win for resource conservation, and even a political win for the politicians. The industry should actively partner with governments where we can to advance this cause, and solid state lighting can be one of the beneficiaries. Solid state lighting is a clear example of where higher initial costs can hide the longer term benefits that come from accelerating the transition – benefits for both the country and the consumer). We should have learned by now that education as we have practiced it in the past will not be enough. We have to make some changes. We must do something different. There are too many different definitions of "rational" to make the educational approach alone effective. It may well be that educating the government can be more effective and much simpler than educating the entire public.

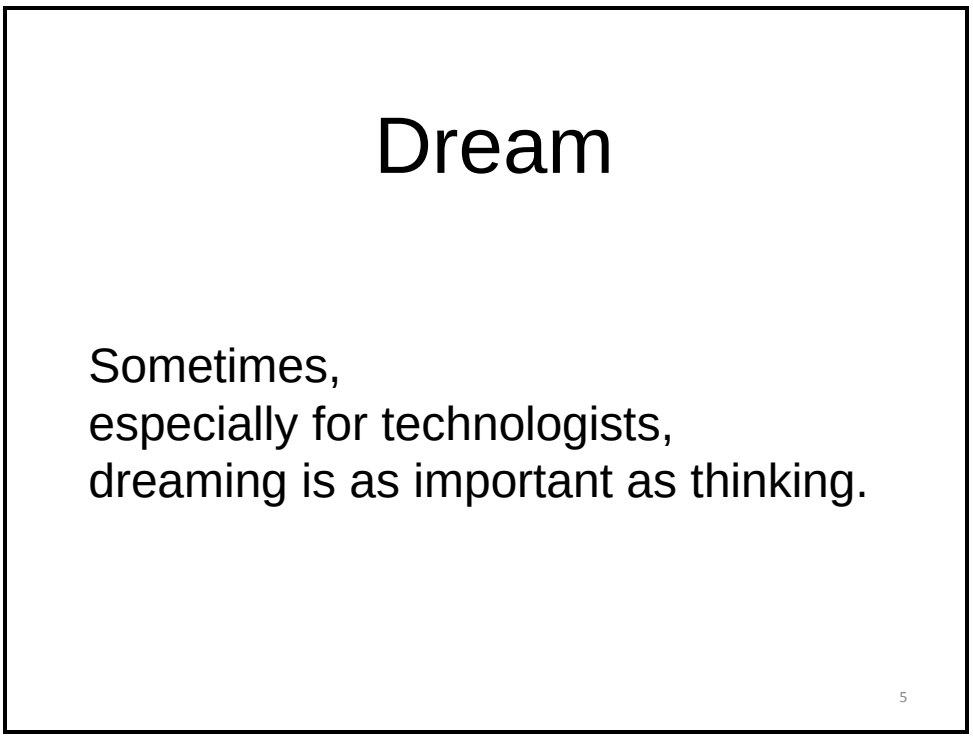
   Our political policy makers say that energy conservation is a high national priority, much higher than consumers are willing to reflect in their daily practice, if left on their own. There is no necessary link between national priorities and my behavior, and yours. When the government needs to conserve gas or oil or steel in times of war, it does not just ask people to try to use less; it imposes a rationing program to forcibly align citizen behavior with national priorities. When your company responds to a severe market downturn with a cost containment focus, it does not just ask the employees to try to save money where they can, but it introduces and enforces cost savings policies to forcibly align employee behavior with corporate priorities. The same is true for water management with local municipalities in times of drought; they don't rely only on good intentions to cut down water use – they mandate it. Good public policy and consumer preferences are not automatically aligned. Sometimes governmental market intervention is required. More than consumer education is needed. It is a new world. It's a world that needs dreamers – product dreamers, application dreamers, value dreamers, political dreamers. Maybe government partnering can be part of such dreaming.

      Here is one such political dream, with a global focus. A company or a consortium of companies goes to the government of a developing country and offers to design and produce a SSL off-grid product for the masses. The product would only have the features that the government asks for or agrees to pay for. The government then buys the lamps and gives them to its citizens. The politicians who support

this giveaway can point to their generosity and remind the voters of it at election time. Politicians exist to get re-elected; this could be a big win for the incumbents. Isn't this a good use for public money – better than most uses for which this money is often spent? In any case, the appeal here is not to the public good – that is far too rational in an engineering sense – the appeal is to the re-election of the politicians, something they can easily understand and appreciate. Such an approach can create demand where there is none today, and can be a huge plus for people and for our industry. It can be a demand that people are most reluctant to give up once they have experienced the freedom that lighting brings. Is this just a pipe dream?

Closer to home, what if our government or perhaps the utilities in the U.S. were to subsidize SSL retrofit lamps so that it was financially neutral for consumers, but saved the U.S. or the utilities more money than the subsidies cost – more money than the cost of new power plants, for example? Could this happen? Is this too bold of a dream?

[slide 4]: DREAM



Sometimes, especially for technologists, dreaming is as important as thinking.

The color rendering index.

All of you know it and its history and its limitations better than I. The CRI is, to the best of my knowledge, the only internationally agreed upon method for color rendering evaluation. For many years, the problems with today's CRI have been well documented. Yoshi (and surely others) have proposed specific steps to improve its weaknesses. I think that most but not all of these steps are broadly accepted. Yet, year after year goes by and no improvements are made. This seems to be a case where the perfect is the enemy of the good; while we debate subtle points forever, a number of widely agreed upon improvements remain unimplemented. This is not surprising; painfully slow progress is the norm for standards organizations. The focus tonight is not with the CRI itself, but with the way we communicate, or fail to communicate, the color properties of a light source to the non-engineering public. The metrics we have on our box and in our literature and in our standards may be fine for communicating from one engineer to another, or within the CORM community, but may be nearly worthless in promoting advanced lighting products to consumers. Most lamp purchasers, both in the consumer and commercial channels, have no clue what CRI stands for or what it implies or how it is measured. And why should they? They are not engineers. To educate the public on this would be a monumental, if not an impossible task. This will be so even if a new CRI or CQS or some other improved system is implemented.

When a lamp company puts CRI 75 on a box or in its catalog, what thoughts do we think run through the purchaser's mind when he or she reads this? In past years, before I retired, I had many conversations on this subject. My conclusions are these:

For most customers:

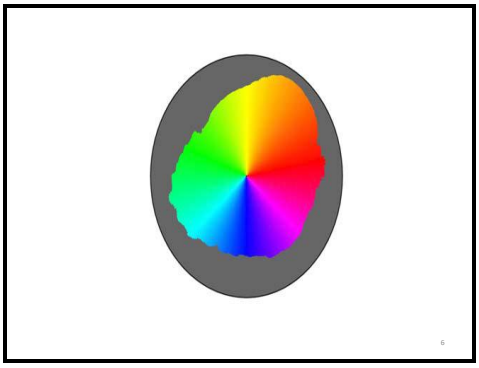
- they don't know what the acronym stands for, they don't much care, and they spend almost no time thinking about it; it has not even occurred to many of them that different lamps would render colors differently
- when told what the acronym stands for, they don't know what it means
    - some think it is related to "naturalness"
    - others "color discrimination"
    - still others think it has something to do with "vividness" or something similar that makes me think they are talking about saturation
    - some guess that the CRI is about "pleasing colors," whatever that means
    - almost no one says "the way colors look compared to a reference lamp" [in any case, they would not know what the reference lamp is]
- even if told what the index means, and what the maximum value is, they have little idea how to interpret the number 75.
    - they may assume the scale is 0-100, which, though wrong, has some meaning
        - but even then, they don't know if 75 is good; do any lamps have higher values? do most lamps have higher values? do most lamps have lower

values? Is 50 an average value? [Interestingly, the industry usually doesn't put CRI values on packages of incandescent or halogen "reference" lamps.]

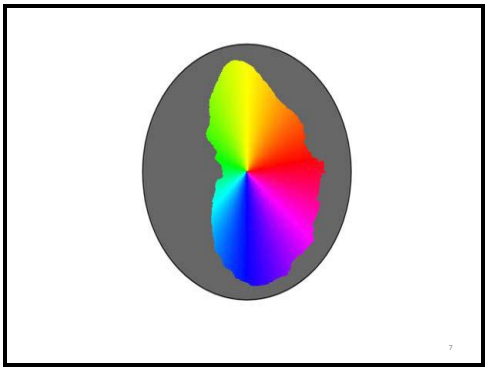
- they may think that 100 is a theoretical maximum that is never meant to be achieved or even approached in practice?

This represents a lost opportunity for communicating value to customers. Is effective communication only the responsibility of marketing departments? Do metrologists also have some responsibility here? Even if they don't have a responsibility in their job description, isn't this a chance to think and act about a problem that no one else seems to know how to deal with? Is this a good opportunity for CORM to probe, to prod, to experiment, to lead, to dream? Maybe by describing such a metric, marketing departments can see the missed opportunity and finally start to communicate color rendering to the public. Such a metric doesn't have to be a number, though it will almost surely be calculation-based.

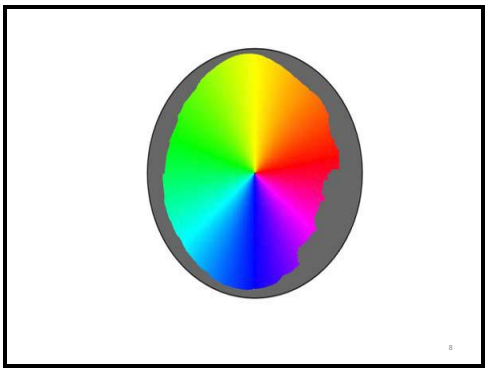
About 5 years ago there was a conference to explore just this opportunity. Some of you were there. Several suggestions were made, but one of them captured the most attention, and I highlight it here tonight. The proposal came from two Europeans, Peter van der Burgt and Johan van Kemenade. Their suggestion was not to use a number at all, but a picture. [slide 5].



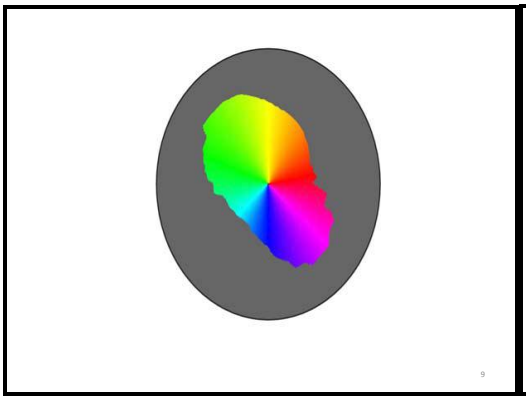
This is for a fluorescent lamp. This one [slide 6]

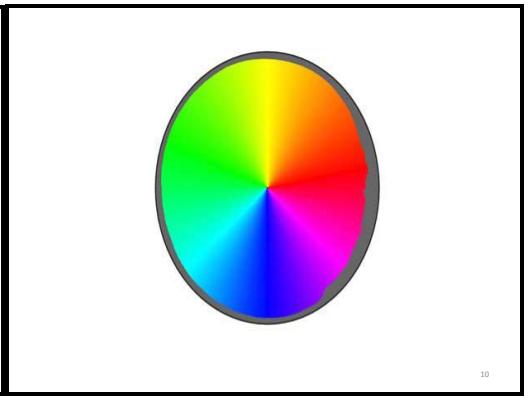


is for a different fluorescent lamp. This one [slide 7]

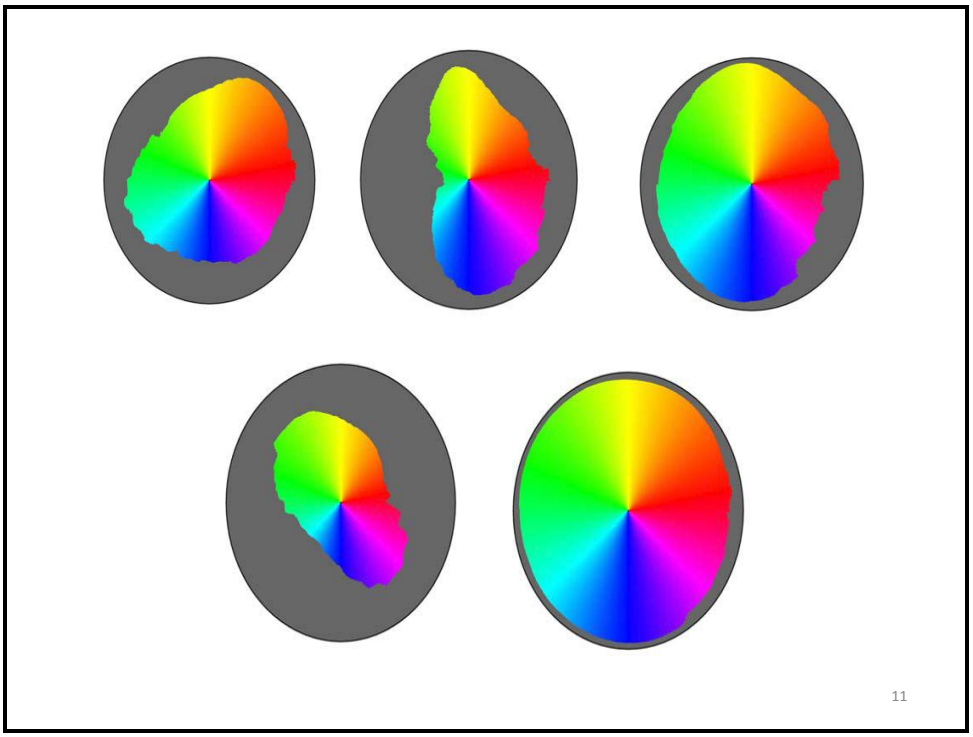


is for a third kind of fluorescent lamp. The last two [slides 8 and 9]





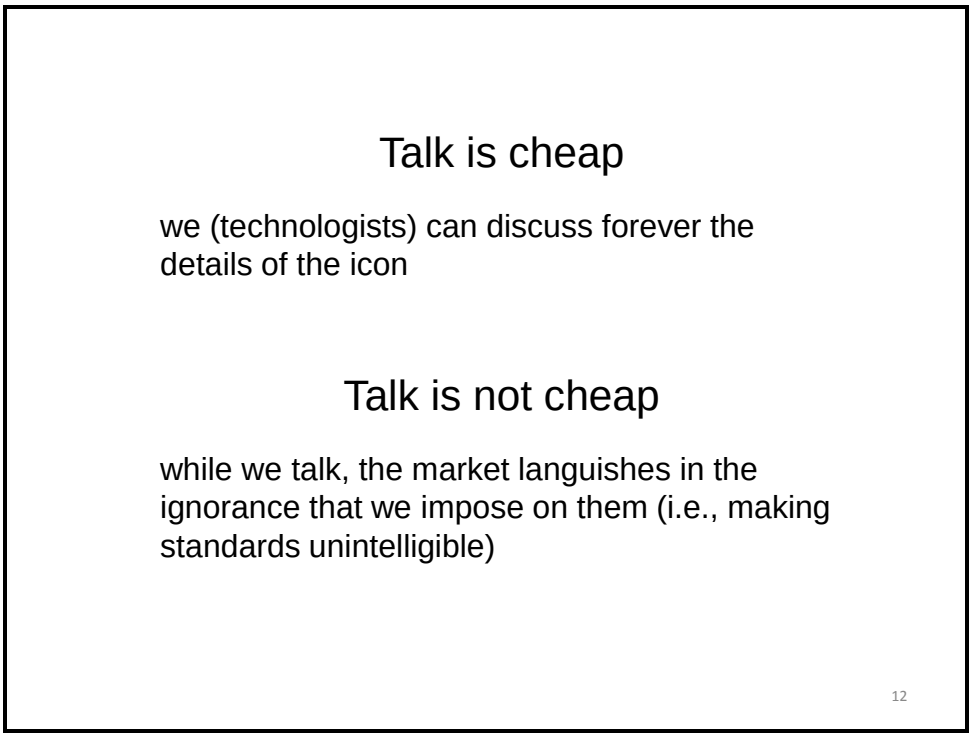
are for two different LED lamps. Here [slide 10]



all five icons together, for comparison. In follow-up discussions with NIST, both Wendy and Yoshi suggested improvements to this approach, even allowing the colored region to go outside the circle if the test lamp was more saturated at that hue than the reference lamp. Some approach

like this would be a huge improvement in the communication of a lamp's color rendering properties, even allowing for a range of possible interpretations of "rendering." And yet, five years later, there is no concerted effort to adopt or even to define the metrics on which such a picture is to be based. Is five years too little time? Is communication that actually has commercial value too far removed from the charter of standards organizations? Are we missing a golden opportunity to dream, when in fact we may be among the most qualified people to dream in this field?

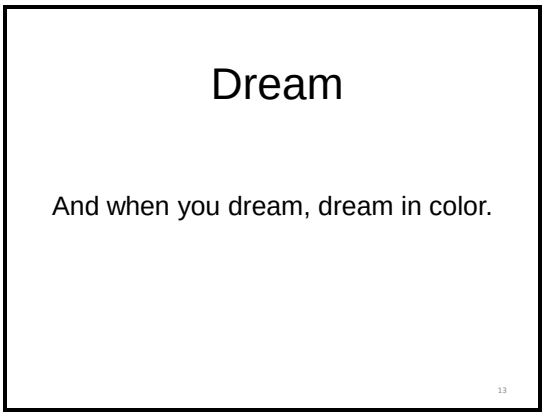
Sometime we have to stop talking and start acting. Show slide 11.



My hope: someone or some group here tonight will champion the cause for detailing and implementing a commercially intelligible metric **for color rendering or color quality or color appearance or whatever we wish to call it.** The communication vehicle may or may not be based on the icon approach I have shown.

[slide 12] DREAM

AND WHEN YOU DREAM, DREAM IN COLOR



The Light Bulb Law (also incorrectly called the light Bulb Rule) being discussed in Congress these days.

In December 2006 Philips issued a public call to effectively phase-out the inefficient household incandescent lamp, and they were specific that government action was required in order for this to happen. This was a dream. It was clear from decades of experience that market forces alone would not give this result. Within a few months, all major western manufacturers and many NGOs supported this movement. The result today is that several countries have responded with legislation, including the U.S. and the EU. Sometimes, dreams come true. Perhaps you see this as a bad dream coming true. I know there is a movement underway in Congress, especially among Republicans, to repeal this legislation, and they may succeed. The debate has had its share of intentional misinformation, but this is to be expected in politics. My view is that this legislated phase-out is an example of good public policy. The facts are that today's inefficient incandescent lamps would be replaced by more efficient halogen incandescent lamps (as one option) that cost about $1-3 more and save about $3 in energy costs. With no net cost to consumers, with no necessary change in light quality, and with hardly a discernible change in the physical lamp appearance, the country saves energy at a time when conserving energy is a national priority. The net money flow is from utilities to retailers and lighting companies. This not so bad, not only from a lighting company perspective, but from a public policy viewpoint as well. Left to the consumers' individual decisions, such a win-win switch would probably never occur if the less efficient incandescent lamps were left on the market; education is too slow, too ineffective, and too uncertain.

Here are three perspectives on this Federal law that you may not have thought about.

1. First, it is very interesting that – before the law was passed -- none of the big lamp companies offered such an energy saving halogen incandescent lamp to replace the less efficient incandescent lamp, even though the technologies were not new. Perhaps they did not think there was a market for such a product. In broad terms, this more efficient halogen technology could have been used to offer three different kinds of product improvements: (1) more lumens for the same watts and life (with no energy savings); (2) the same lumens for the same watts with longer life (with no

energy savings); or (3) the same lumens for less watts and the same life (with energy savings). In fact, some lamp companies did offer products with this technology, but in the form of longer life products, not energy saving ones. Presumably their market research indicated that "short life" was a bigger dissatisfier than "too high" energy costs. One perspective on this law is that it is the government's way of telling the public and the manufacturers that "energy savings" needs to be bumped up in priority. In this case, the issue is not technology but commercial responsiveness to national priorities. For the good of the country, the government adjusted the market in a way that cost the consumer nothing in money or performance while saving energy. This phase-out is the kind of legislative leadership we have a right to expect from our politicians. Forty (40) gigawatts of power plant capacity surely has better uses in a financially strapped economy like ours than powering today's inefficient incandescent lamps. Federal action is warranted and appropriate.

2. A second perspective: Our government gives tax breaks and even more direct financial incentives for generating energy from wind and solar and other green technologies. For my tax money, it is better to curb energy use and free up power plant capacity at no cost to consumers or the government than promote technologies that require government subsidies (i.e., my tax dollars) to fund.

3. Third, there is one more perspective to underscore the industry's willingness, even eagerness, to support this Federal law. At the time the Federal legislation was drafted, there were movements underway in several states to separately pass their own versions of lamp efficiency standards. There was every likelihood that these state laws would not be consistent with each other. (States are jealous of their authority.) The industry wanted to avoid that different lamps would have to be made and marketed for different states. This is perhaps the most compelling reason for the industry to back a federally legislated solution. (By the way, many NGOs would have welcomed a state-by-state battle with the industry.)

This is not to say that government involvement in our business is good in general, or that it is without its risks. When it saves consumers money with no loss of lighting quality or change in style while saving energy, with net environmental benefits, it seems like a no-brainer to me. Other examples could be given of government intervention which has had a damaging effect on our business, without compensating benefits to the consumer, but that's not a subject for tonight's talk.

Dream

And encourage others
To dream along with you.

It could be the most
important thing you do.

14