

The Economics of Nuclear Power

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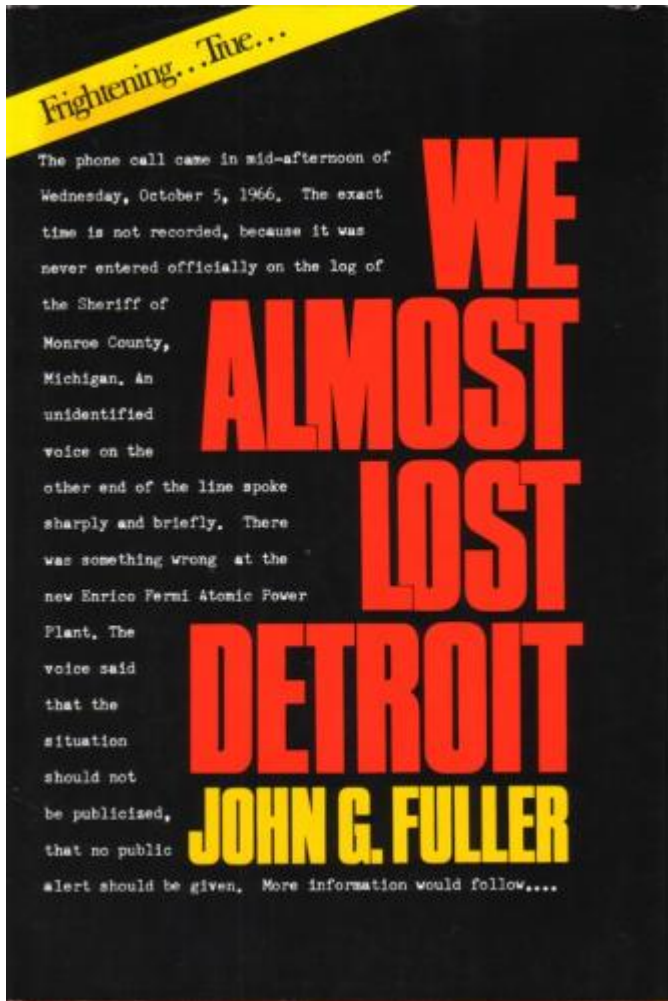
Introduction: Three problems

- Nuclear power would be a clean, effective energy source for the future *if* three problems were solved:
 1. Limits on available fuel supply
 2. Challenges of safe, affordable plant operations
 3. Need for secure, *very* long-term waste disposal plans
- It is likely that none of these problems can be solved
 - Any one of them is enough to rule out reliance on nuclear power for the future
- All of them reflect the danger of radioactive materials

Fuel supply problems

- Almost all natural uranium is U-238, which does not sustain fission reactions
- Natural supplies of (fissionable) U-235 will last a few decades at current rate of use
 - Expansion of nuclear power would exhaust supplies sooner
- Likely solutions
 - Dirtier mining of lower-grade ores (compare to tar sands)
 - Development of breeder reactors
 - Different (faster) fuel cycle converts U-238 to (fissionable) plutonium, allows use of more nuclear materials

Breeder reactors: The U.S. experiment

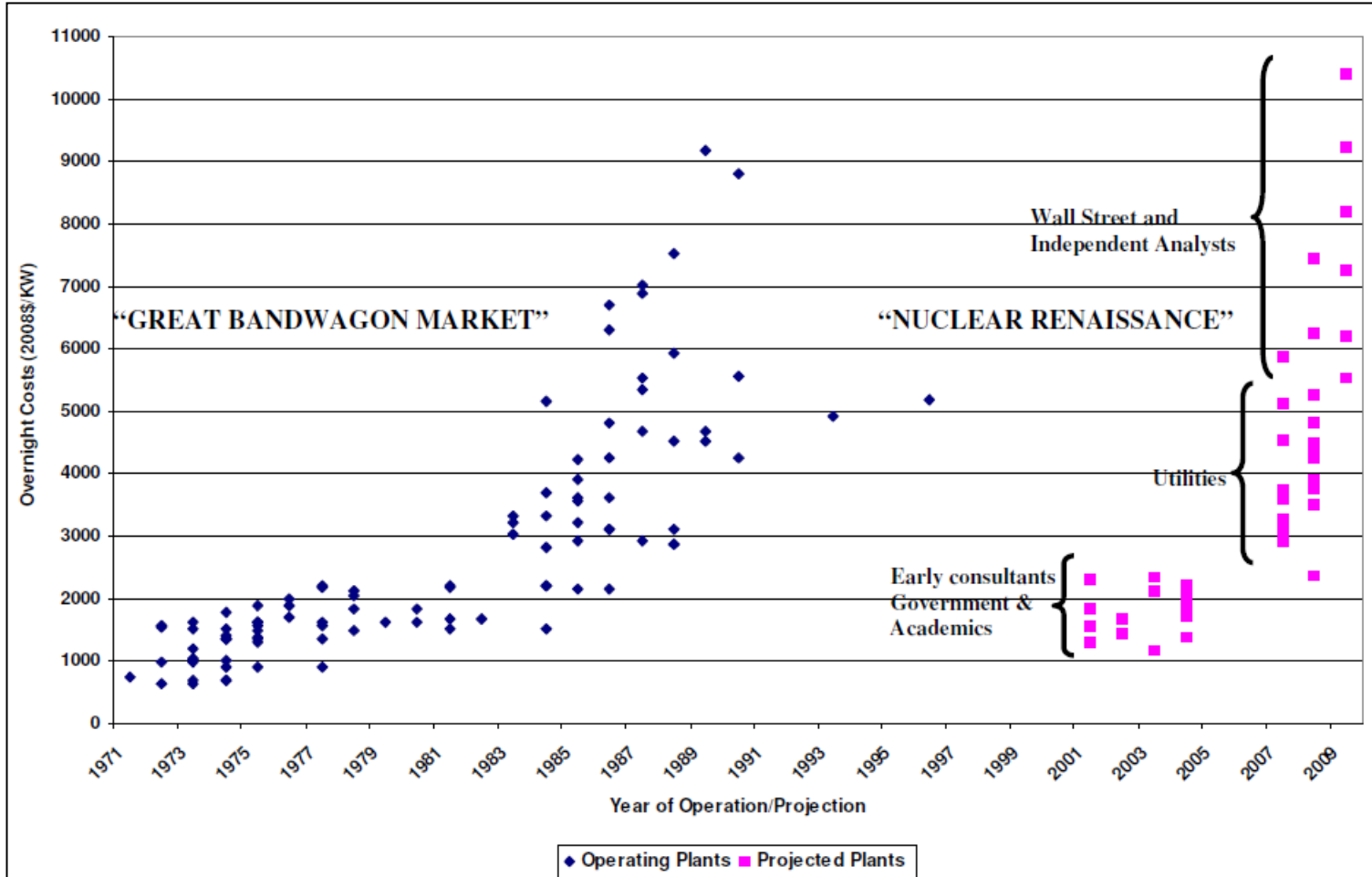


**WE DID
NOT
ALMOST LOSE DETROIT**

A Critique of the John Fuller Book:
"We Almost Lost Detroit"

Detroit
Edison

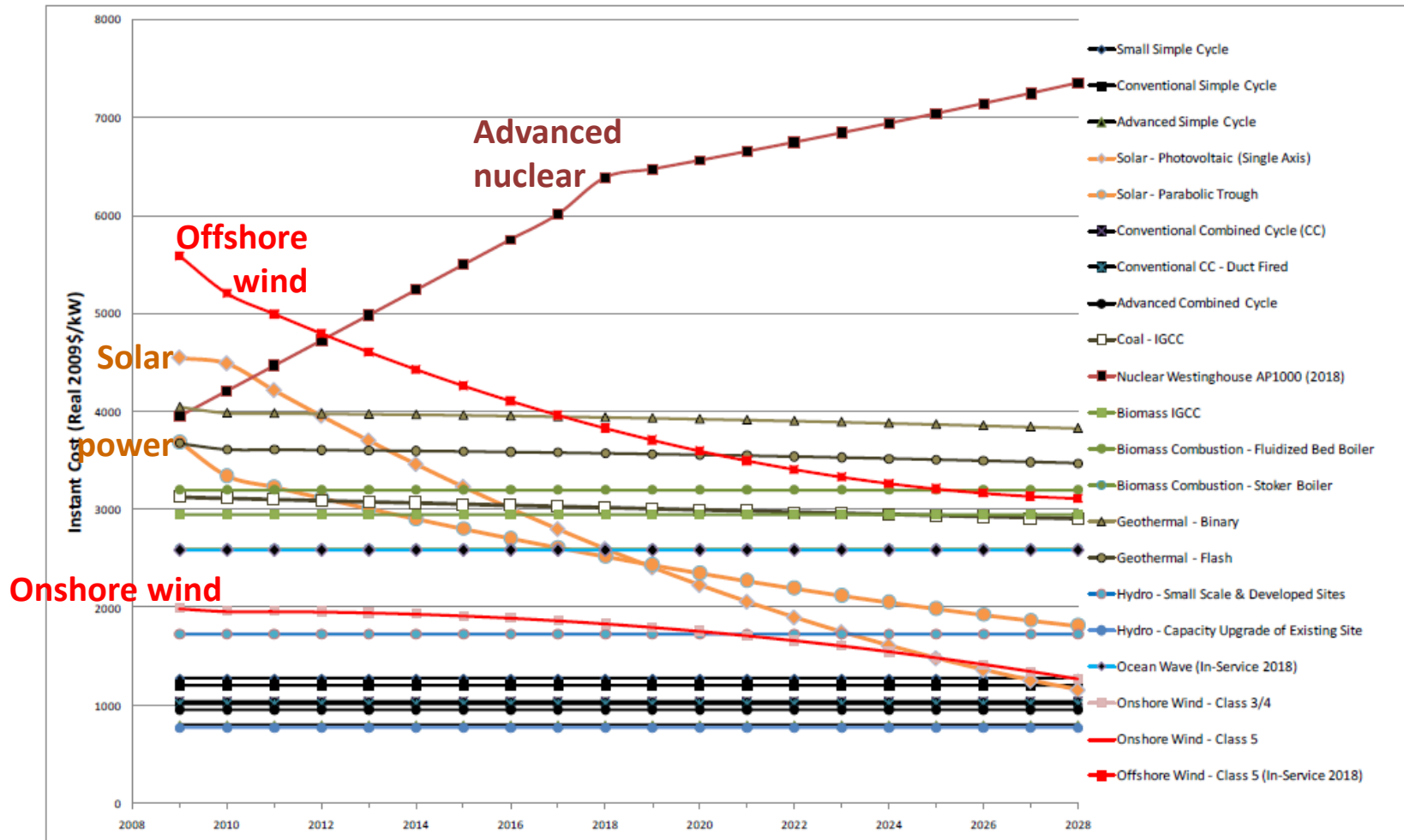
Rising costs of nuclear power



Overnight capital costs, by year of operation or projection

Mark Cooper, "The Economics of Nuclear Reactors: Renaissance or Relapse?", 2009

The rising experience curve



Overnight capital costs per kw, 2008 – 2028. California Energy Commission, *Comparative Costs of California Central Station Electricity Generation, 2010*

Accidents will happen

- Why do nuclear costs rise with more experience?
 - Safety hazards are endless
 - Each can be fixed, at a price
 - Cumulative cost of fixing all known hazards keeps rising
- Browns Ferry accident (1975)
 - Fire destroyed wires to emergency core cooling system
 - Solution: dig up concrete floor, install two redundant, widely separated sets of wiring
 - Perfect safety solution *to this problem*; very high cost



Nuclear waste is (almost) forever

- Nuclear power creates large volumes of waste that are hazardous for $\sim 10,000 - 100,000$'s of years
- Analysis across this span of time is all but impossible
 - If we care about outcomes many millenia from now, the discount rate must be zero
 - Alternative: non-standard analysis with explicit value on indefinite future, sustainability (Chichilnisky)
 - If the discount rate is positive, the far future doesn't matter
- Planning for safe waste management is impossible across thousands of years

Thousand-year communications

- Suppose the world of 1,000 years ago had wanted to send us a message about hazardous waste
- Laws, regulations: how many governments today were in existence in the year 1011?
 - *Iceland*
- Elsewhere, who remembers government edicts of 1000 years ago?
 - Holy Roman Empire?
 - Empires overthrown by Incas and Aztecs?
 - Several dynasties ago in China?

English, 400 years ago

Shakespeare,

original spelling

ROMEO & JULIET, SECOND QUARTO, 1599

Corus. Two housholds both alike in dignitie,
(In faire Verona where we lay our Scene)
From auncient grudge, breake to new mutinie,
Where ciuill bloud makes ciuill hands vncleane:
From forth the fatall loynes of these two foes,
A paire of starre-crost louers, take their life:
Whose misaduentur'd pittious ouerthrowes,
Doth with their death burie their Parents strife.
The fearfull passage of their death-markt loue,
And the continuance of their Parents rage:
Which but their childrens end nought could remoue:
Is now the two houres trafficque of our Stage.
The which if you with patient eares attend,
What heare shall misse, our toyle shall striue to mend.

English, 600 years ago

CANTERBURY TALES (1387 – 1400)

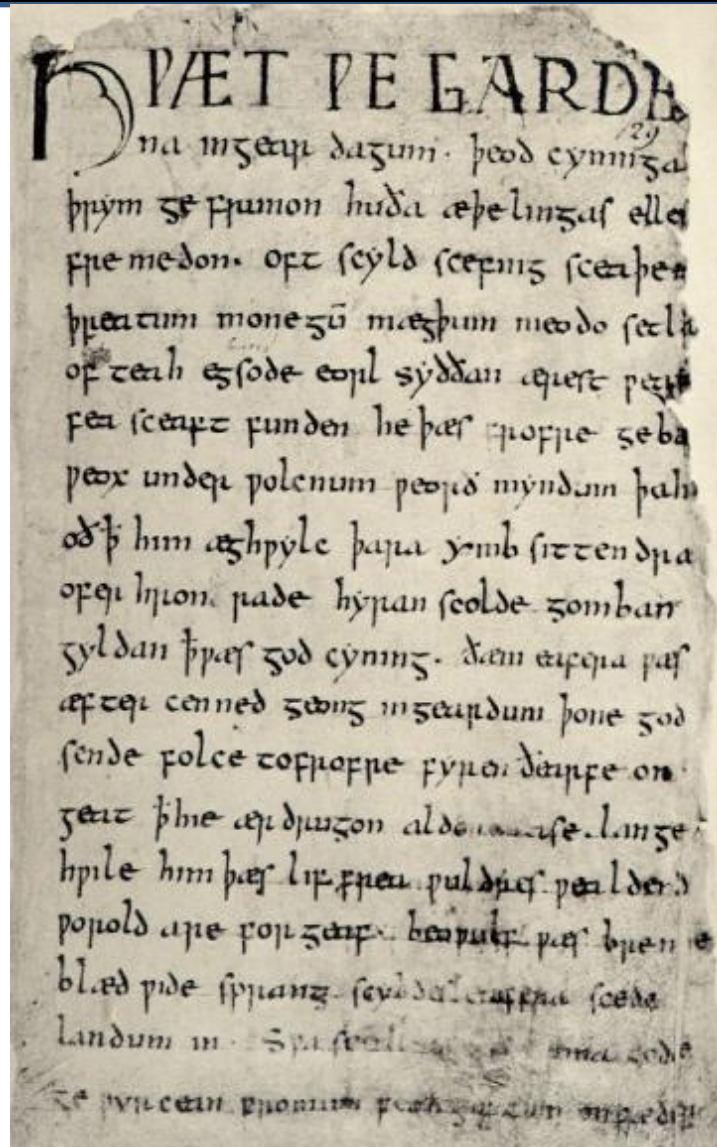
Whilom, as olde stories tellen us,
Ther was a duc that **highte** Theseus;
Of Atthenes he was lord and governour,
And in his tyme **swich** a conquerour,
That gretter was ther noon under the sonne.
Ful many a riche contree hadde he wonne,
What with his wysdom and his chivalrie;
He conquered al the regne of Femenye,
That whilom was **ycleped** Scithia,
And weddede the queene Ypolita,
And broghte hir hoom with hym in his contree,
With muchel glorie and greet **solempnytee**,
And **eek** hir yonge suster Emelye.
And thus with victorie and with melodye
Lete I this noble duc to Atthenes ryde,
And al his hoost, in armes hym bisyde.

*Chaucer,
original spelling*

*Red = words that are
most changed in
modern English*

English, 1000 years ago

- Beowulf, the classic epic poem
- Written in “Old English” about 1000 years ago
- Most words are incomprehensible
- The alphabet has changed! Some letters are unknown in modern English
- **Can you tell if this is a hazardous waste warning, or poetry about Danish kings?**



Eternal waste management

- Safe management of nuclear waste requires effective communication of hazards across huge spans of time
- Can governments retain continuity for tens to hundreds of times as long as Iceland has?
- Can language remain comprehensible for tens to hundreds of times as long as the time since the old English of Beowulf?
 - *If not, there is no safe plan for nuclear waste*