

# **The Economics of Nuclear Power**

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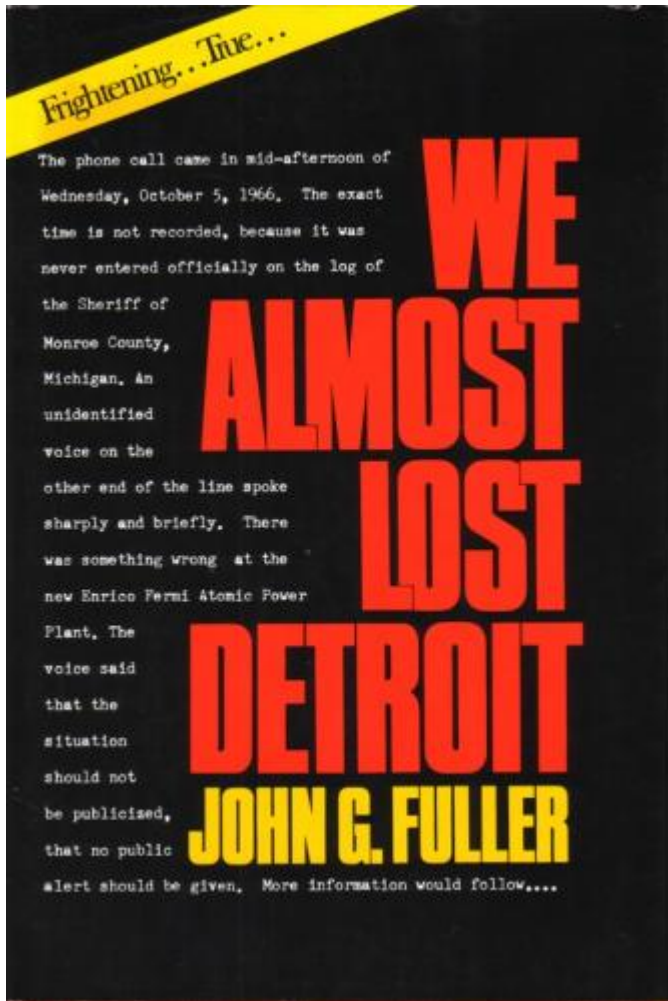
# Introduction: Three problems

- 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

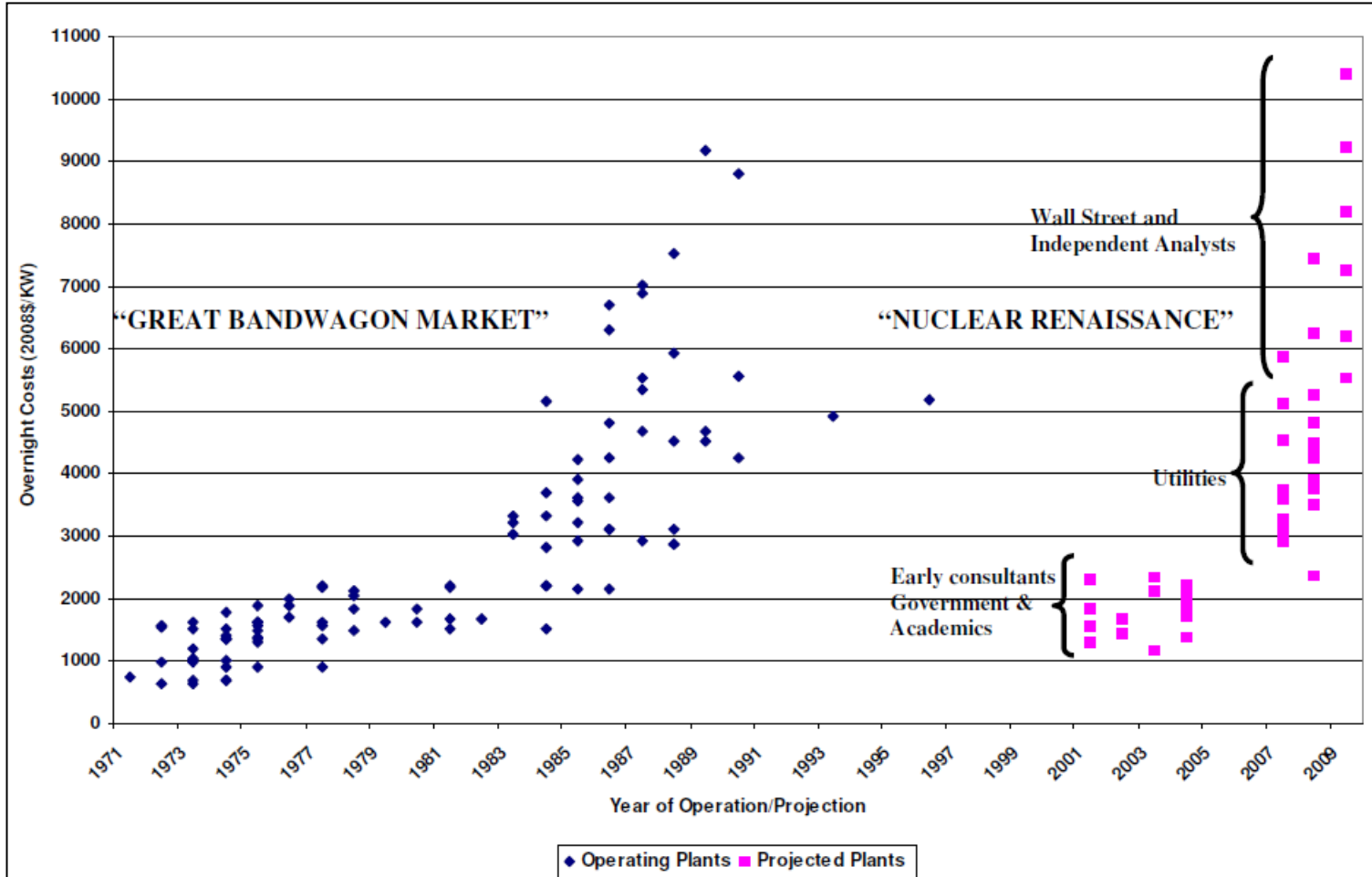


**WE DID  
NOT  
ALMOST LOSE DETROIT**

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

**Detroit  
Edison**

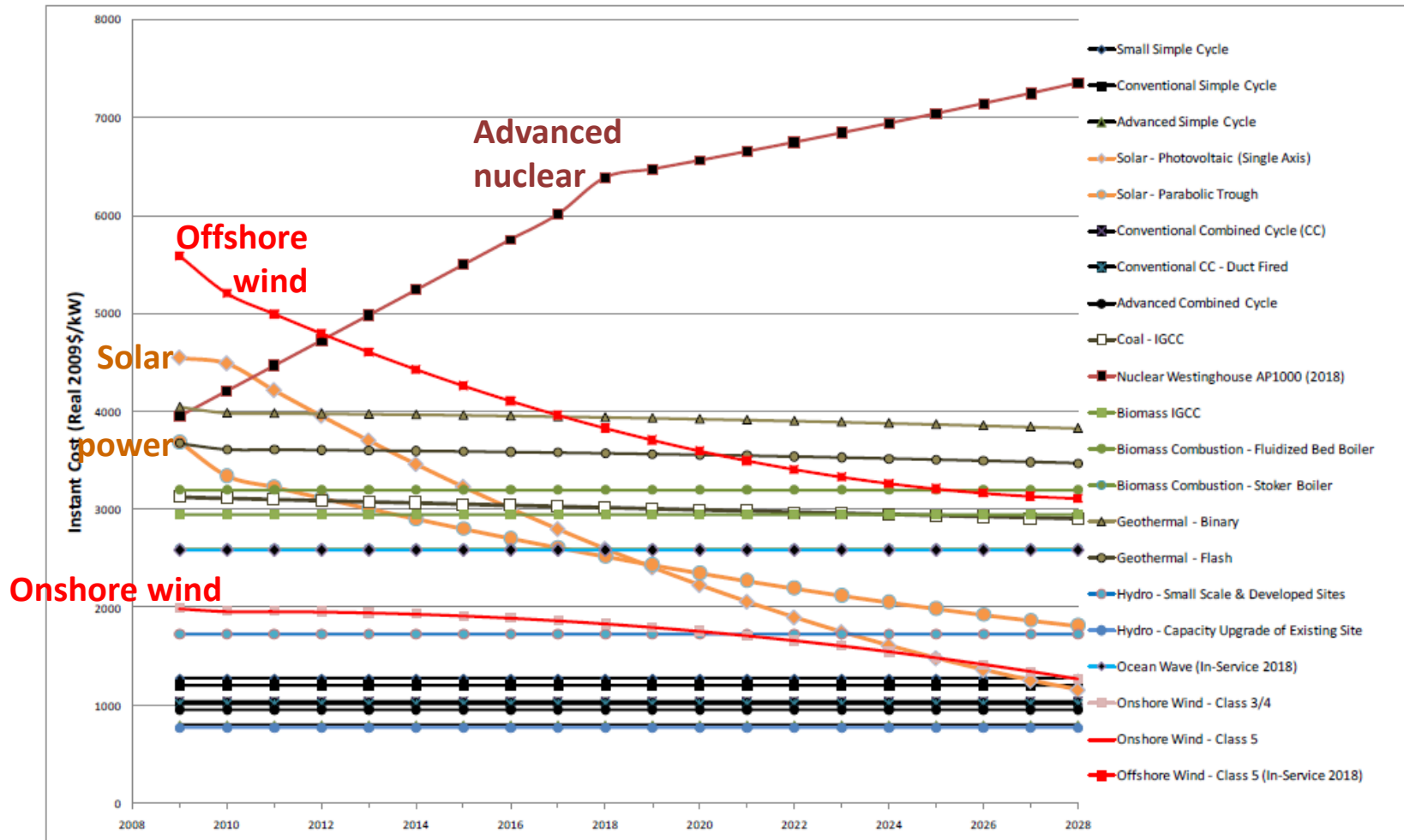
# Rising costs of nuclear power



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)

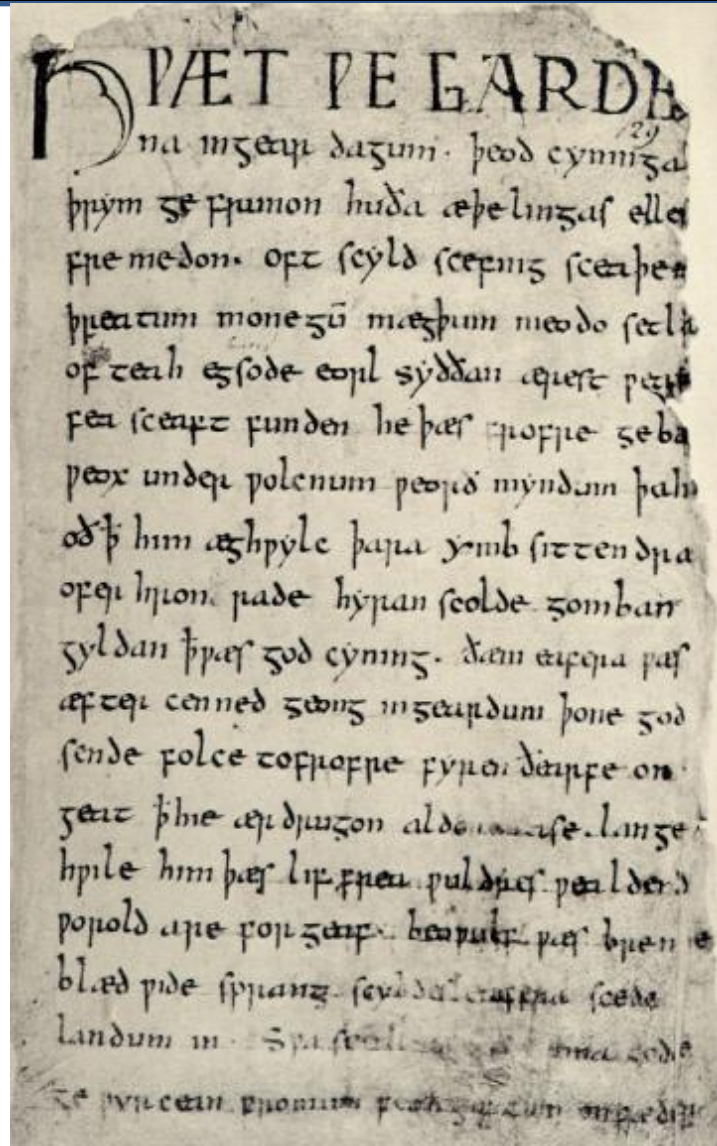
**Whilom**, as olde stories tellen us,  
Ther was a duc that **highte** Theseus;  
Of Atthenes he was lord and governour,  
And in his tyme **swich** a conquerour,  
That gretter was ther noon under the sonne.  
Ful many a riche contree hadde he wonne,  
What with his wysdom and his chivalrie;  
He conquered 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*