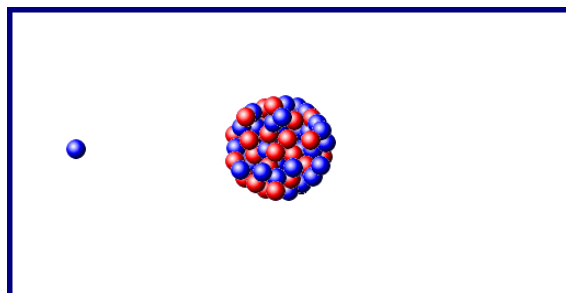


# Werking van moderne kerncentrales

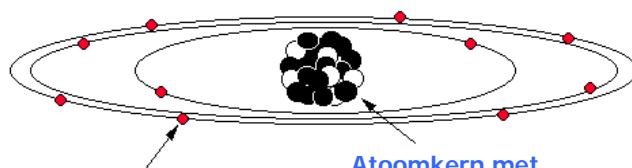


[www.JanLeenKloosterman.nl](http://www.JanLeenKloosterman.nl)

1

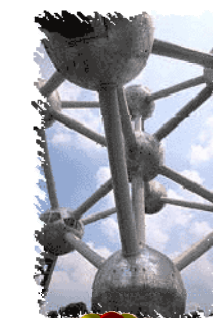


## Uranium



Electronen

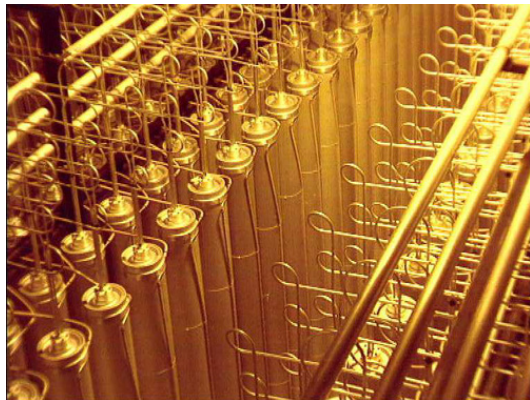
Atoomkern met protonen (p) en neutronen (n)



92 p en 146 n  
Niet splijtbaar  
99,3% voorkomen

92 p en 143 n  
Goed splijtbaar  
0,7% voorkomen

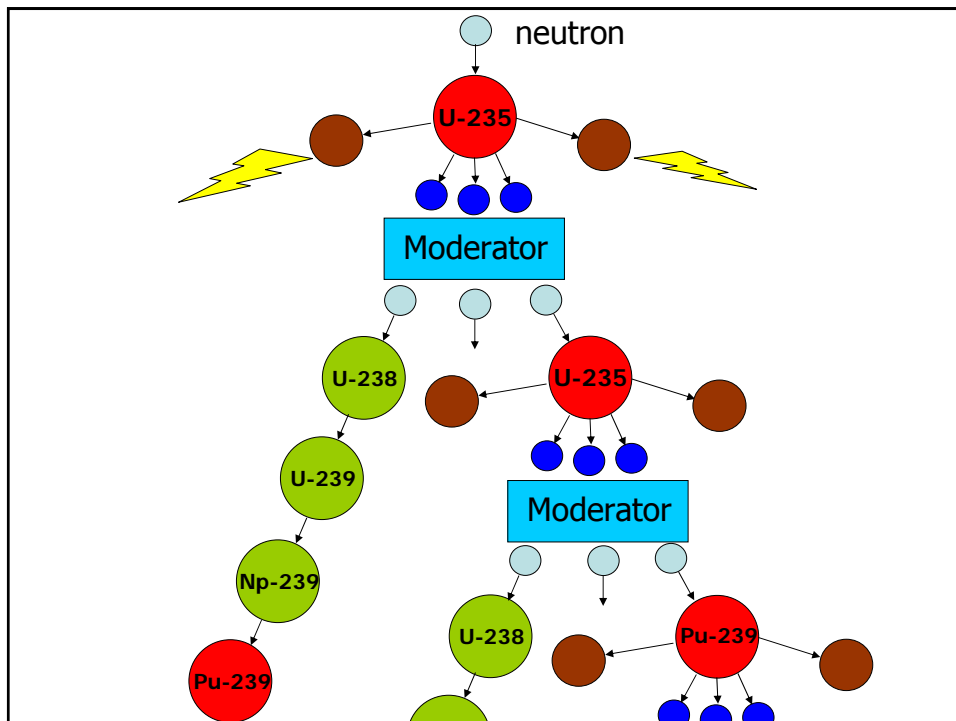
# Uraniumverrijking



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## Energie dichtheid: equivalent van 1 gram



2500 liter



3000 kg

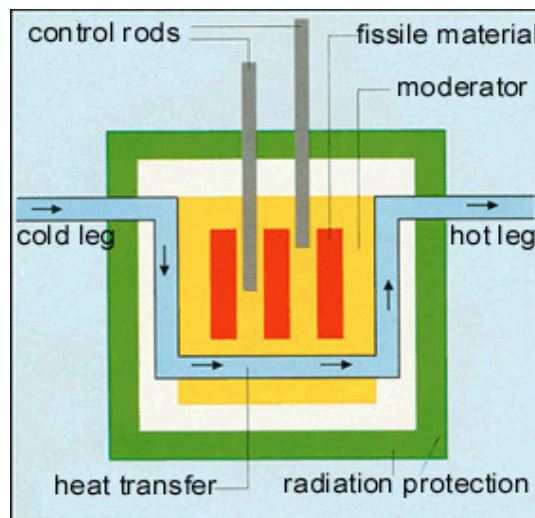
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## Componenten in reactorkern



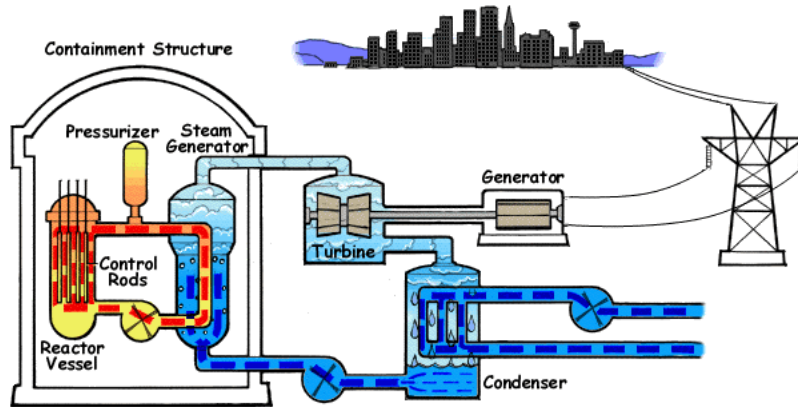
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## Werking van een drukwaterreactor (PWR)



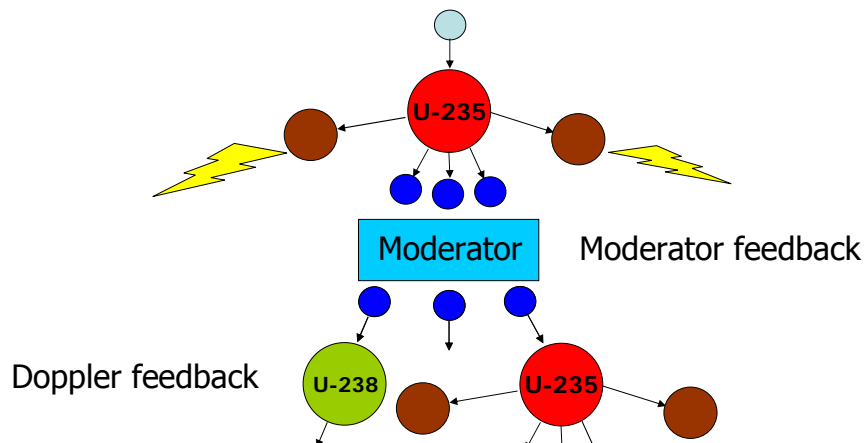
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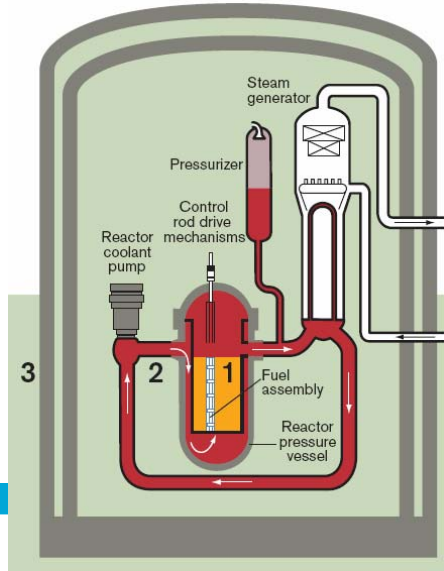
## Veiligheid van lichtwaterreactoren (LWR)



- 1) stabiel systeem (zelfregeling)
- 2) verlies van koelcapaciteit schakelt de reactor af
- 3) verlies van moderatie schakelt de reactor af



## Principe van meerdere barrières



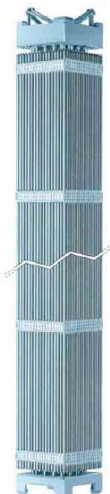
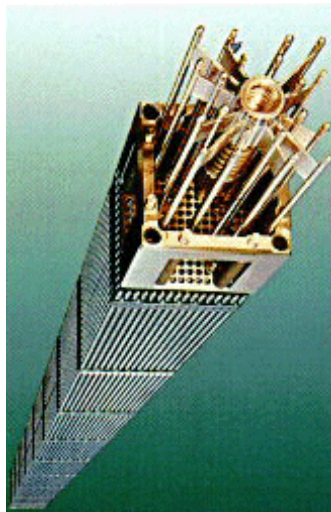
- 1 Splijstof (tablet en bekleding)
- 2 Primair systeem (staal)
- 3 Veiligheidsomhulling (2x beton + staal)

dag Borssele

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## Splijstofelement van een PWR



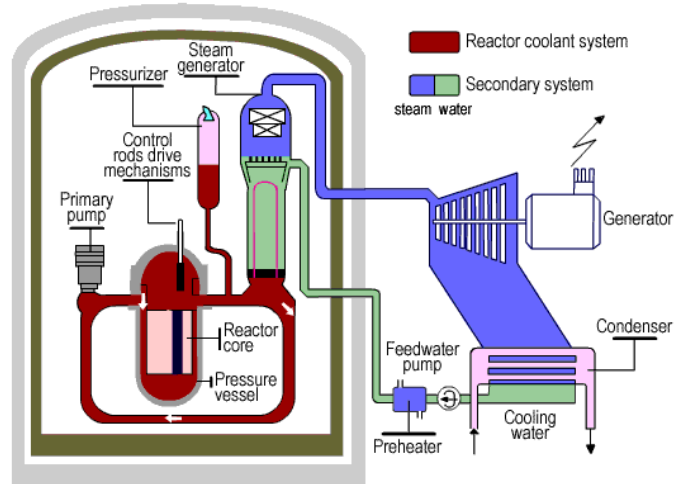
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## Belangrijke componenten in een PWR



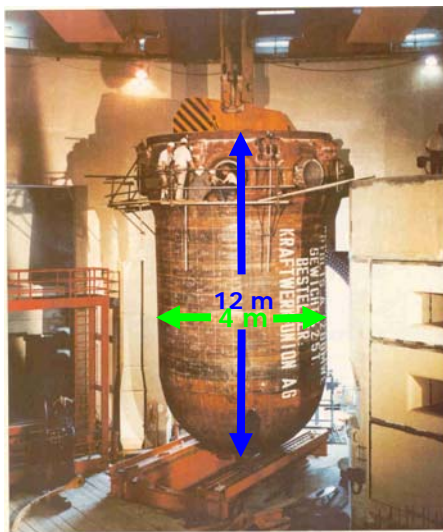
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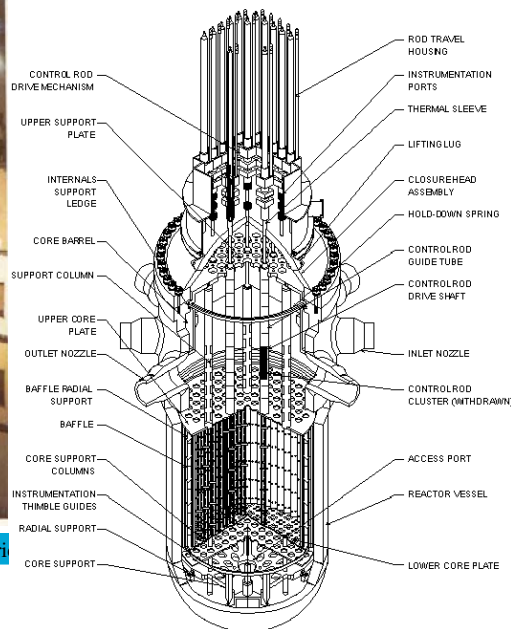
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## Reactorvat PWR

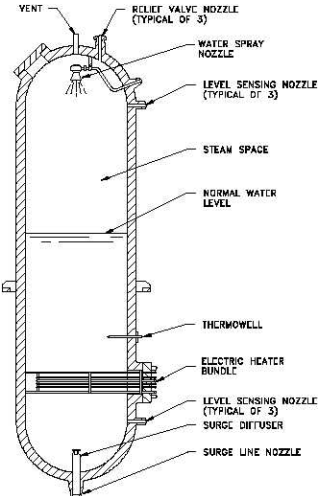


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Industri



# Drukhouder PWR



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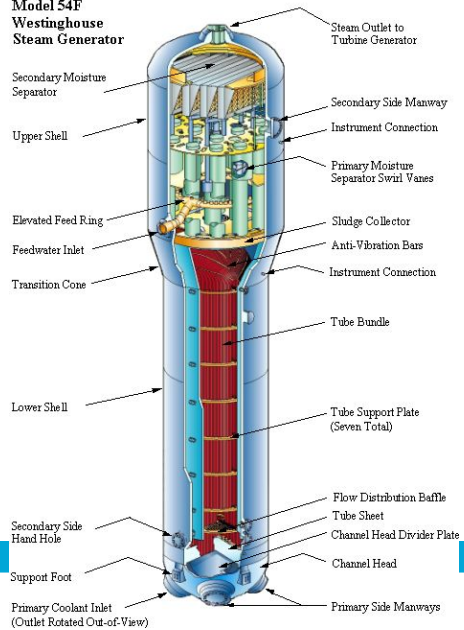
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# Stoomgenerator PWR

Model 54F  
Westinghouse  
Steam Generator



20 m

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## Vervanging stoomgenerator



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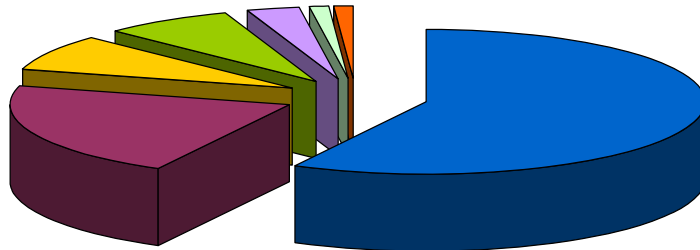
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## In bedrijf zijnde commerciële vermogensreactoren in 2000

(bron: Nuclear Engineering International Handbook 2000)

Totaal vermogen: 364 GWe

- 57,9% Drukwaterreactor (PWR)
- 21,4% Kokendwaterreactor (BWR)
- 7,8% Gasgekoelde grafietreactor (GCR)
- 7,6% Zwaarwaterreactor (PHWR)
- 3,2% Lichtwatergekoelde grafietreactor (LWGR)
- 0,9% Snelle kweekreactor (FNR)
- 1,2% Andere reactoren



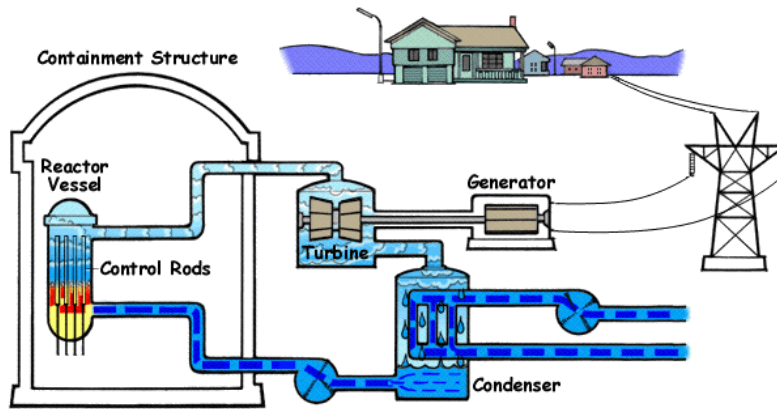
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## Werking van een BWR



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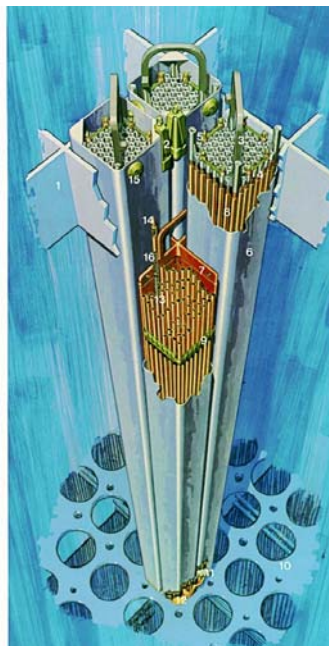
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## Splijstofelement BWR

### BWR/6 FUEL ASSEMBLIES & CONTROL ROD MODULE

- 1.TOP FUEL GUIDE
- 2.CHANNEL FASTENER
- 3.UPPER TIE PLATE
- 4.EXPANSION SPRING
- 5.LOCKING TAB
- 6.CHANNEL
- 7.CONTROL ROD
- 8.FUEL ROD
- 9.SPACER
- 10.CORE PLATE ASSEMBLY
- 11.LOWER TIE PLATE
- 12.FUEL SUPPORT PIECE
- 13.FUEL PELLETS
- 14.END PLUG
- 15.CHANNEL SPACER
- 16.PLENUM SPRING



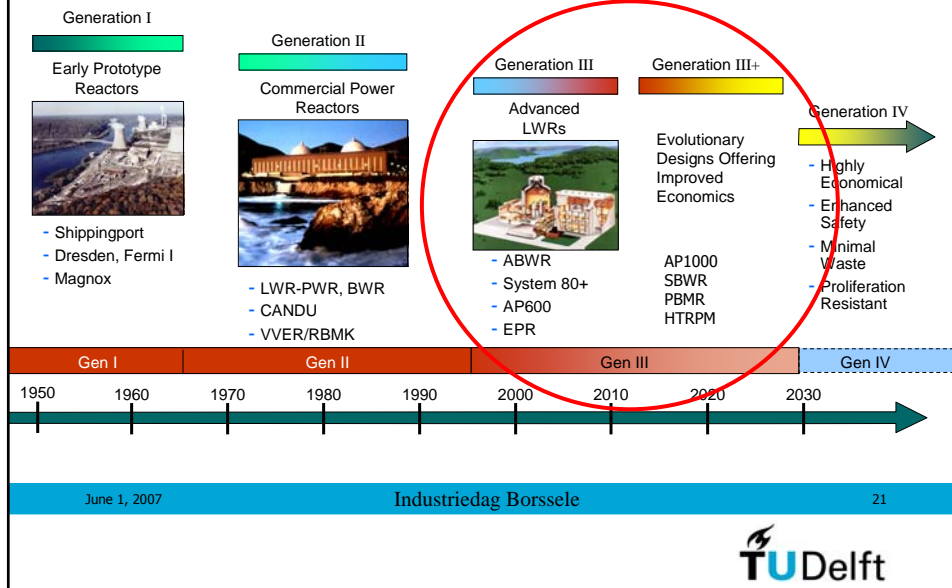
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GENERAL ELECTRIC

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# Generaties kernreactoren



## Defense in depth

1. Design to prevent the occurrence of events (transients) that can result in damage to the fuel or reactor system
  - Negative feedback coefficients
  - Large safety margins
  - Reliable components and well-known materials
2. Protective systems to halt transients
  - Reactor SCRAM systems
  - Pressure relief valves
3. Mitigation systems to limit the consequences of transients
  - Emergency core cooling
  - Emergency secondary feed water systems
  - Emergency electrical systems
  - Multiple barriers to the biosphere

## Defense in depth generation II

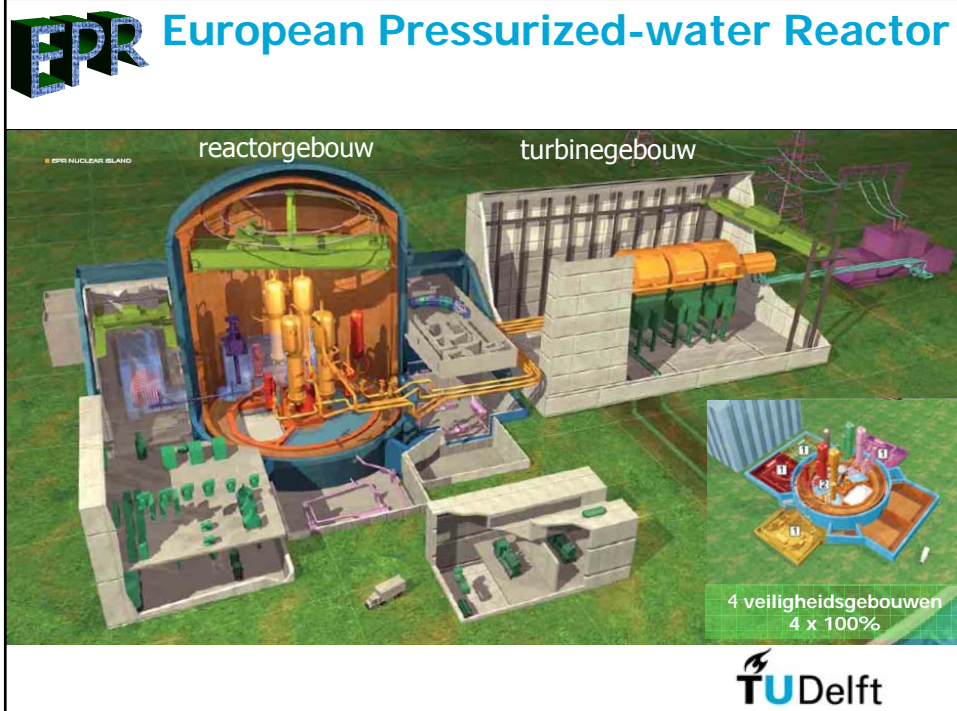
1. Design to prevent the occurrence of events (transients) that can result in damage to the fuel or reactor system
  - Negative feedback coefficients
  - Large safety margins
  - Reliable components and well-known materials
2. Protective systems to halt transients
  - Reactor SCRAM systems
  - Pressure relief valves
3. Mitigation systems to limit the consequences of transients
  - Emergency core cooling
  - Emergency secondary feed water systems
  - Emergency electrical systems
  - Multiple barriers to the biosphere

## Defense in depth generation III

1. Design to prevent the occurrence of events (transients) that can result in damage to the fuel or reactor system
  - Negative feedback coefficients
  - Large safety margins
  - Reliable components and well-known materials
2. Protective systems to halt transients
  - Reactor SCRAM systems
  - Pressure relief valves
3. Mitigation systems to limit the consequences of transients
  - Emergency core cooling
  - Emergency secondary feed water systems
  - Emergency electrical systems
  - Multiple barriers to the biosphere

## Defense in depth generation III+

1. Design to prevent the occurrence of events (transients) that can result in damage to the fuel or reactor system
  - Negative feedback coefficients
  - Large safety margins
  - Reliable components and well-known materials
2. Protective systems to halt transients
  - Reactor SCRAM systems
  - Pressure relief valves
3. Mitigation systems to limit the consequences of transients
  - Emergency core cooling
  - Emergency secondary feed water systems
  - Emergency electrical systems
  - Multiple barriers to the biosphere





## Dubbele veiligheidsomhulling

- beton -
- staal -
- beton -

bestand tegen  
de inslag van  
een groot  
verkeersvliegtuig



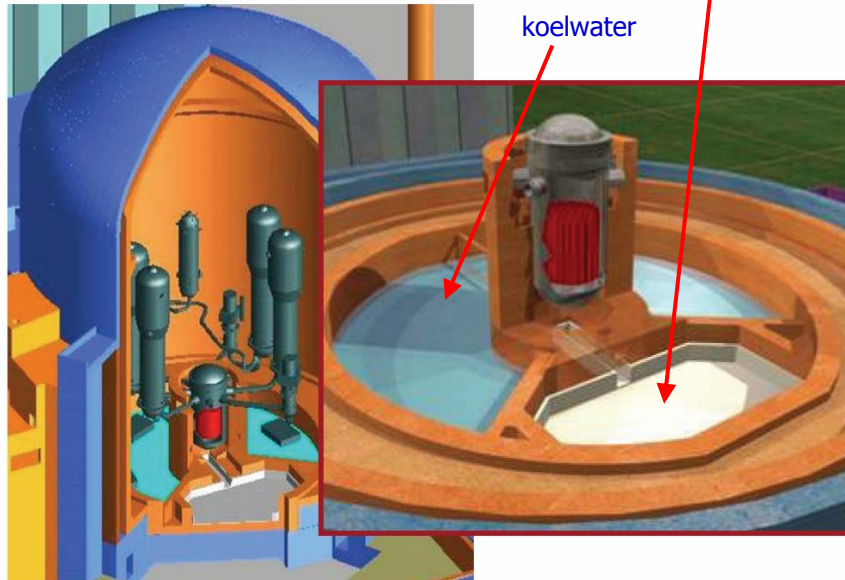
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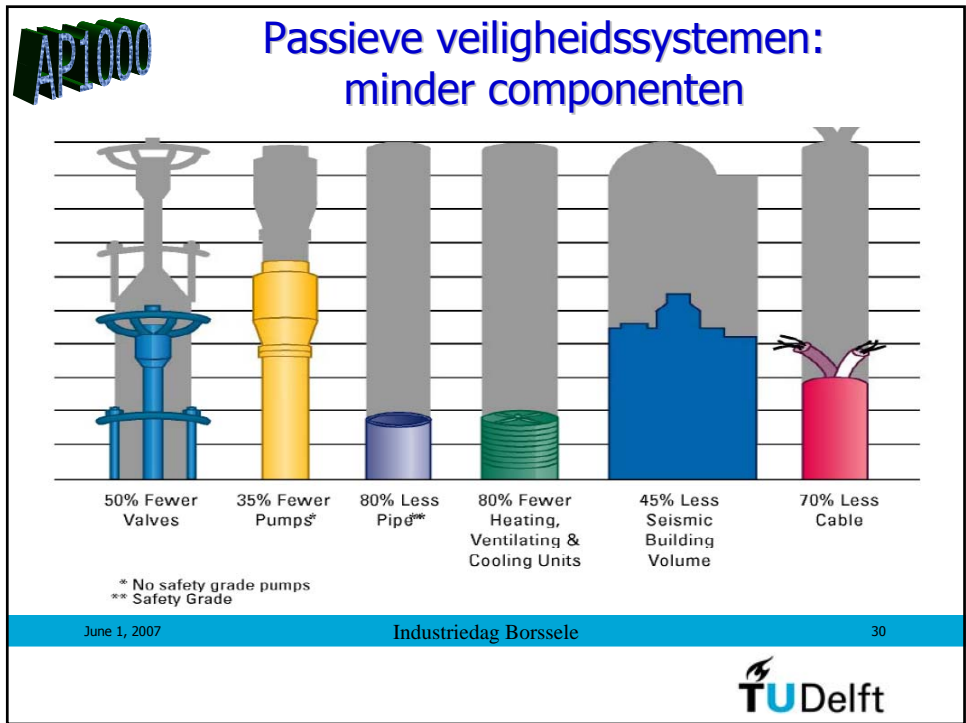
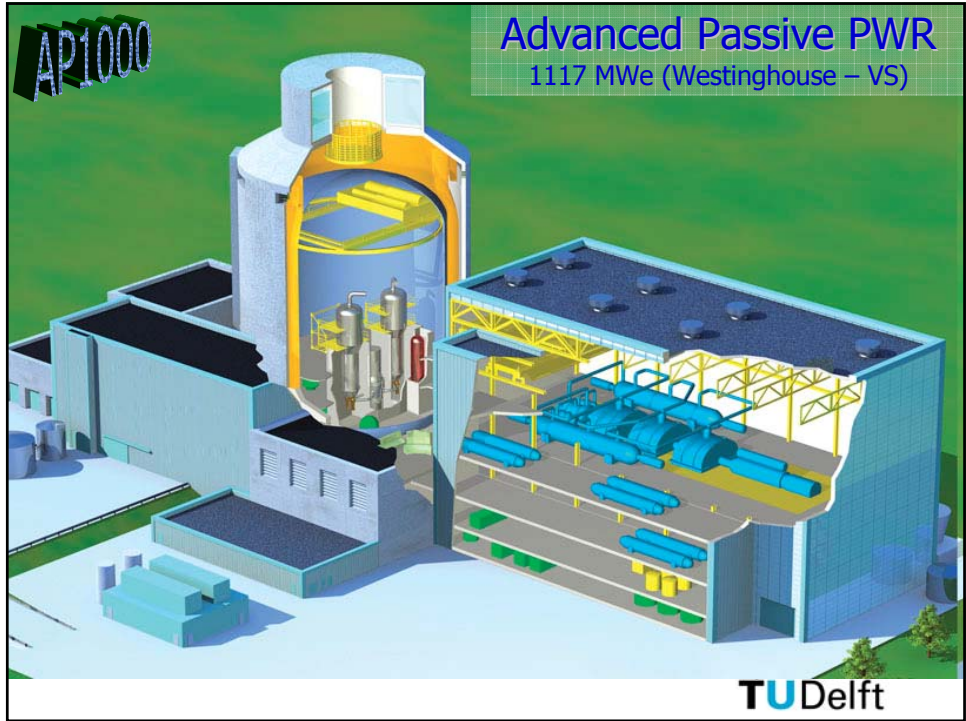
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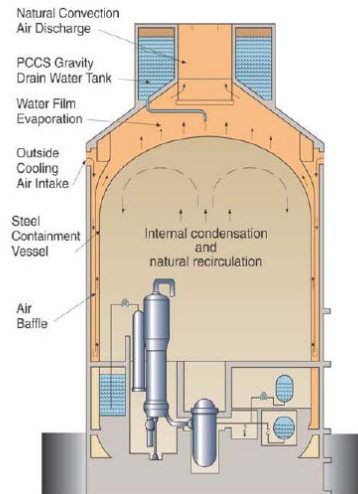
## Passief gekoelde 'Core catcher'





AP1000

## Passieve noodkoeling van veiligheidsomhulling



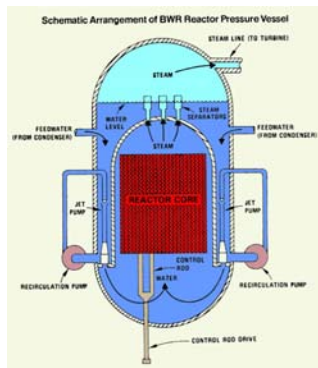
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## Generaties BWR

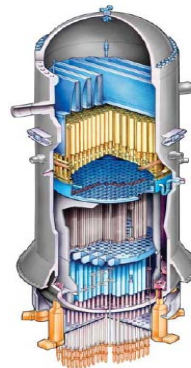
gen II



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gen III  
ABWR

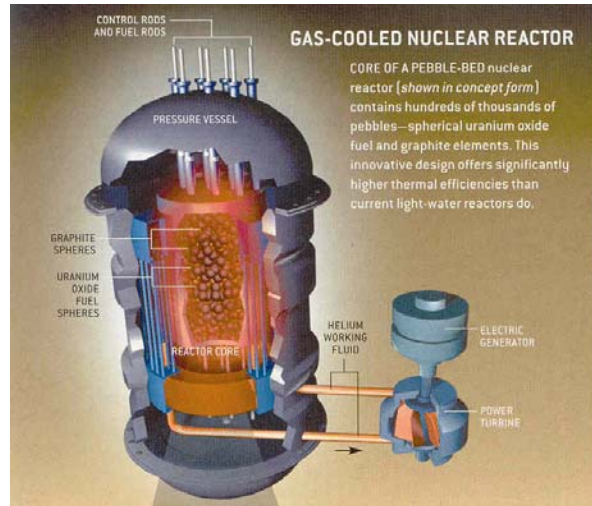


gen III+  
ESBWR



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# High Temperature Reactor (HTR)



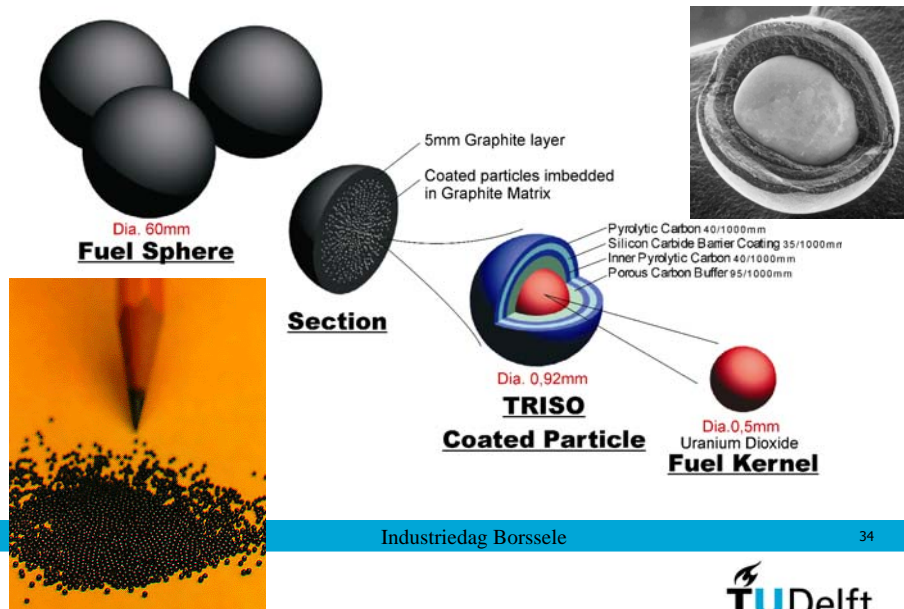
June 1, 2007

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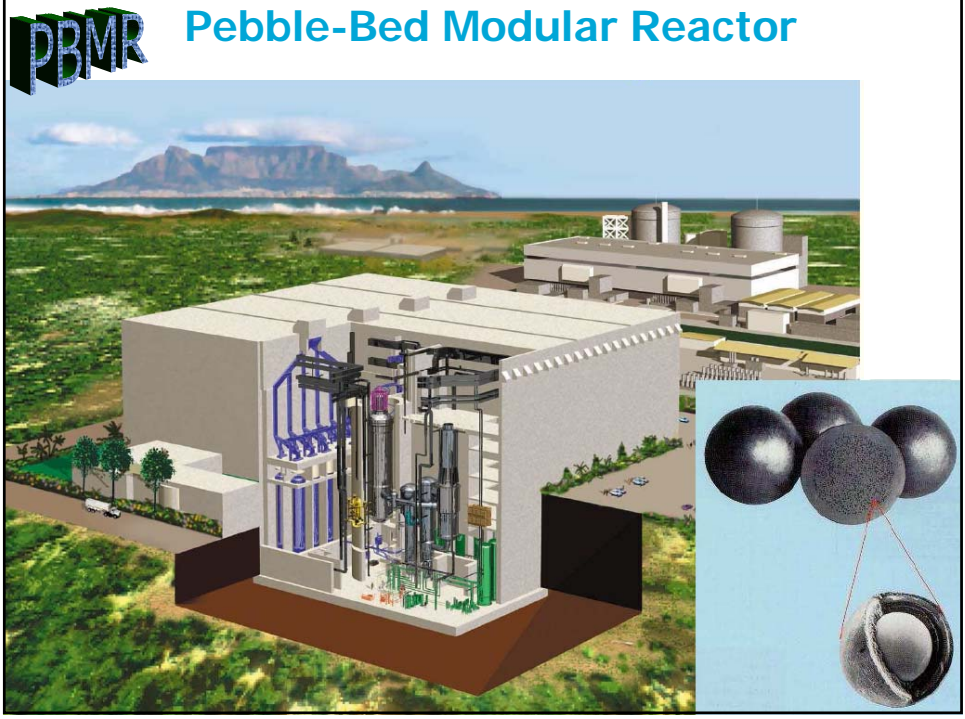
# TRISO splijtstof



Industriedag Borssele

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## Overzicht van moderne kerncentrales

	Generatie III		Generatie III+			
	ABWR	EPR	AP1000	ESBWR	PBMR	HTR-PM
Type	BWR	PWR	PWR	BWR	HTR	HTR
Generatie	III	III	III+	III+	III+	III+
Vermogen	1350	1600	1150	1550	165	190
VS certificatie	ja	2007	ja	2010	nee	nee
In gebruik	3	0	0	0	0	0
In aanbouw	3	1	0	0	0	0
Respijtperiode	72 uur	30 min.	72 uur	24 uur	∞	∞
Kernsmeltfrequentie (1/jaar)	$2 \cdot 10^{-7}$	$1.3 \cdot 10^{-6}$	$4 \cdot 10^{-7}$	$3 \cdot 10^{-8}$	0	0
'core catcher'	nee	ja	<24 uur	<24 uur	onnodig	onnodig
Constructietijd (jr)	4	4	3	3	2	?
Technische levensduur (jr)	60	60	60	60	?	?

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