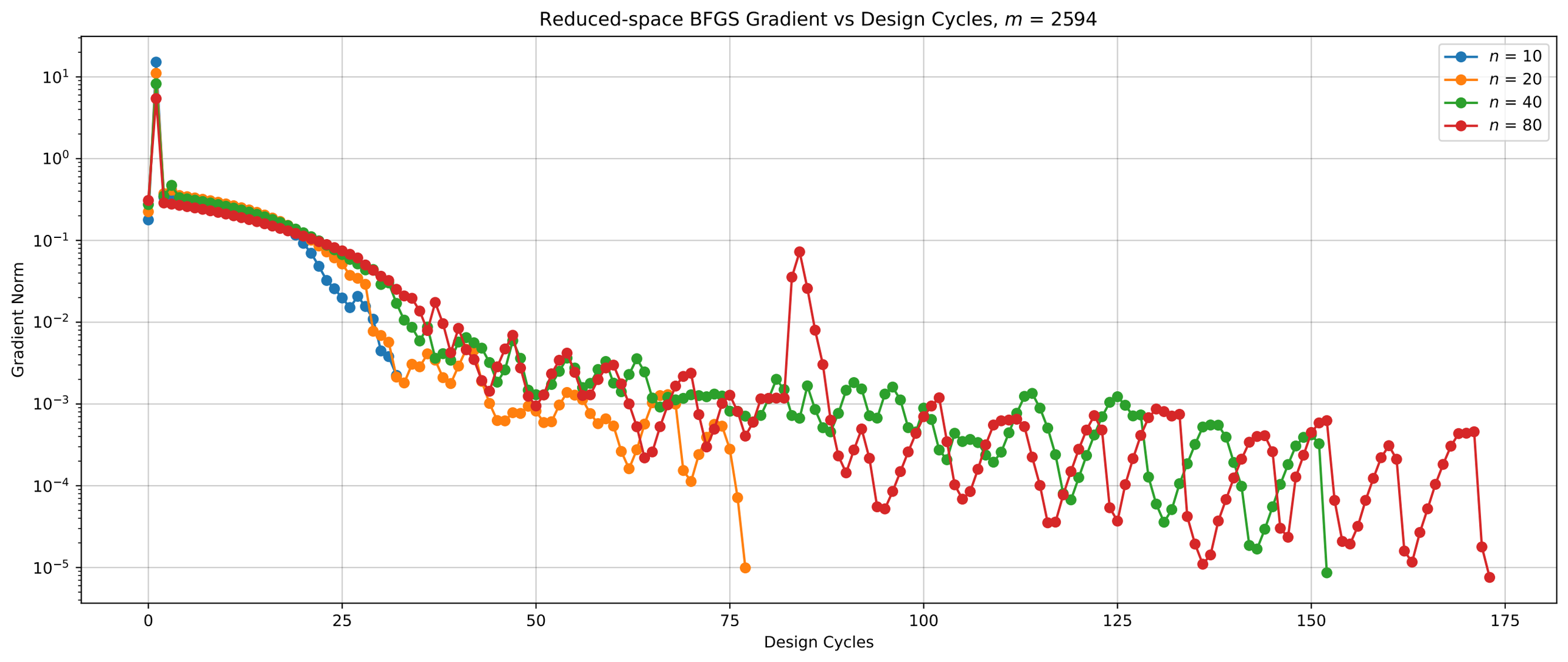
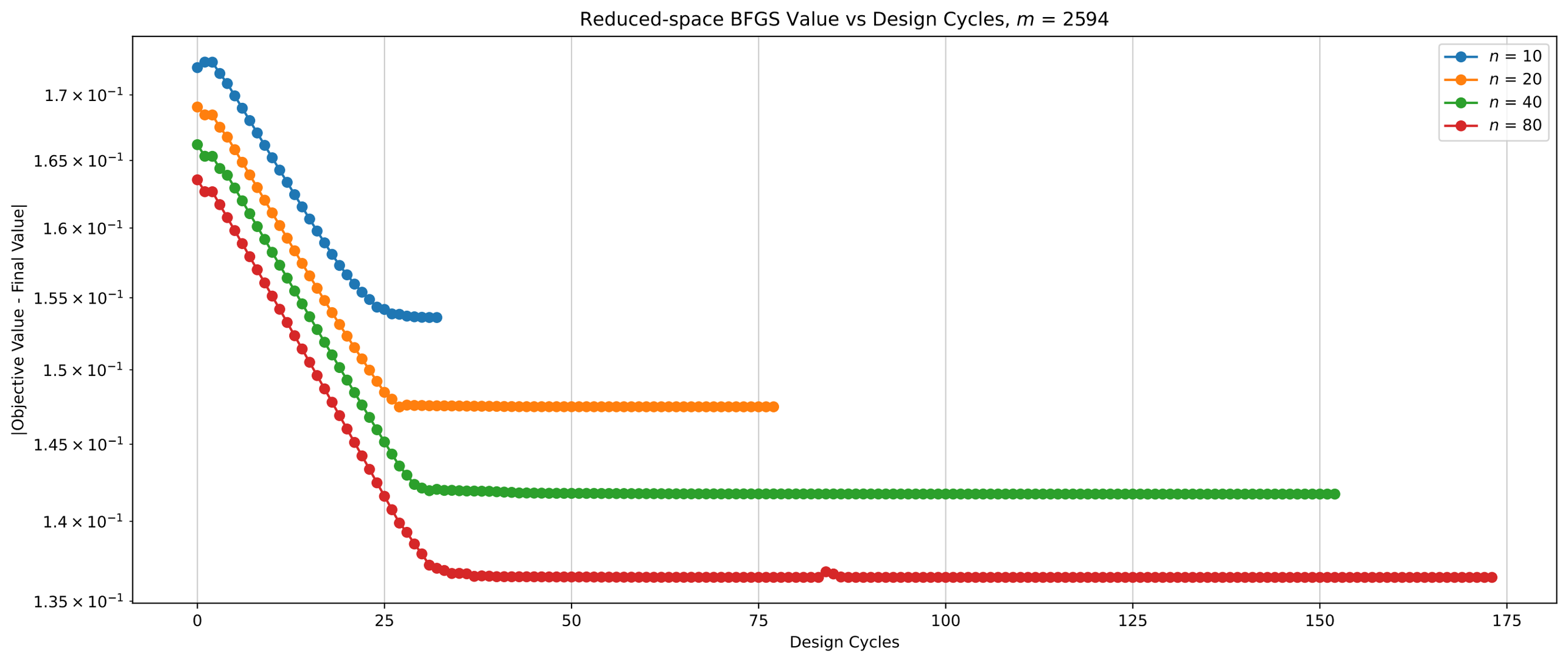
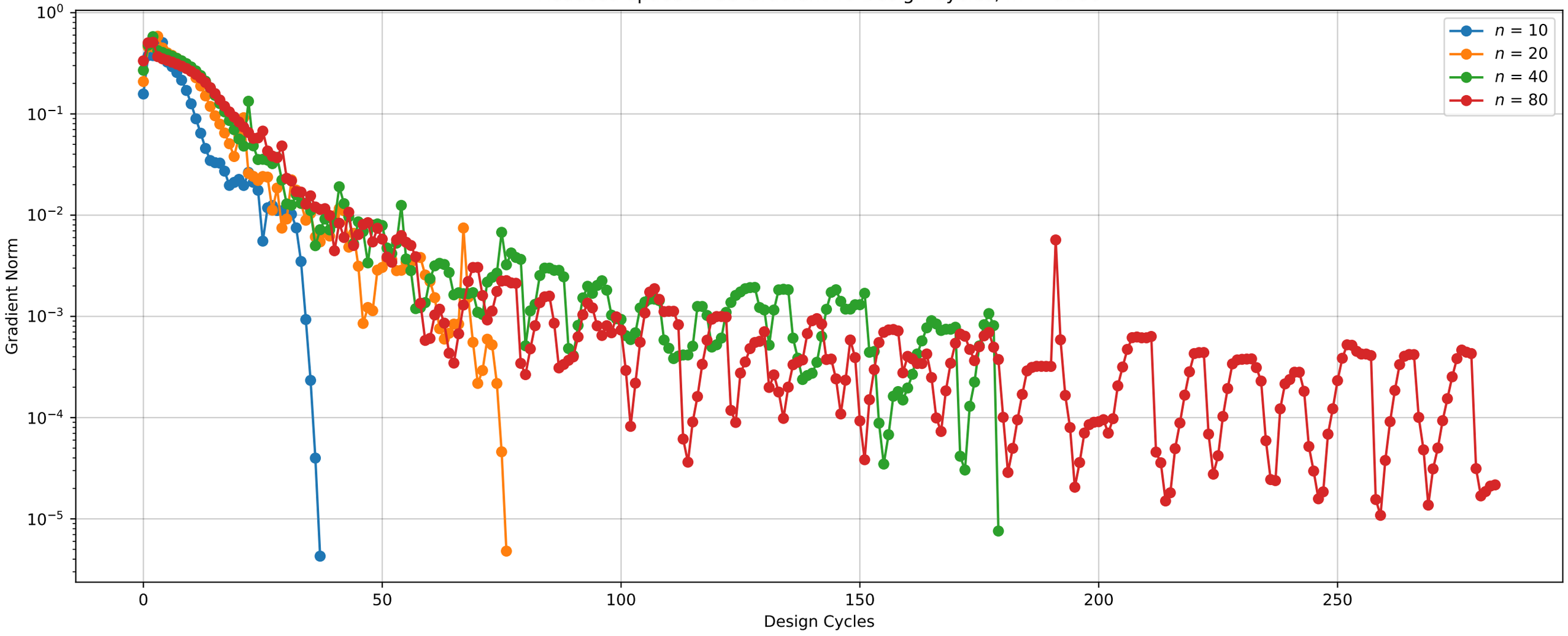
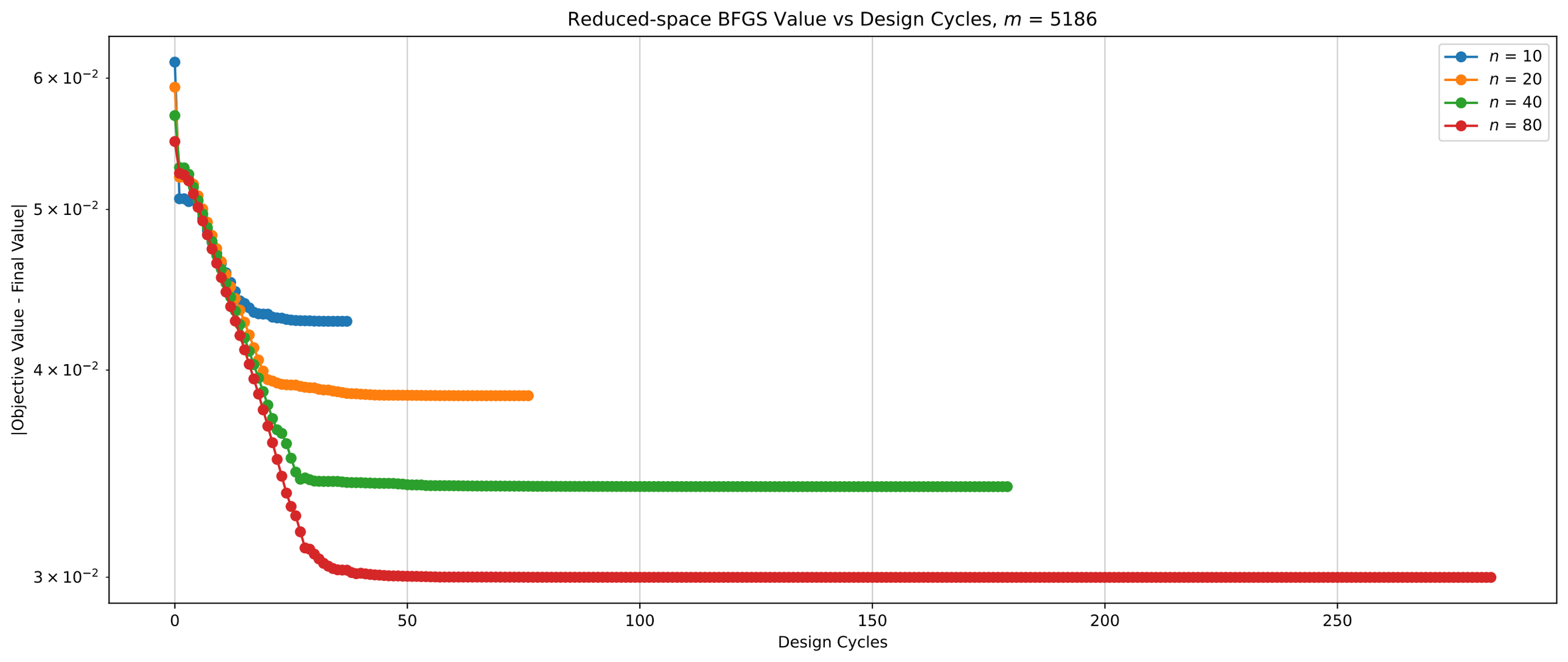
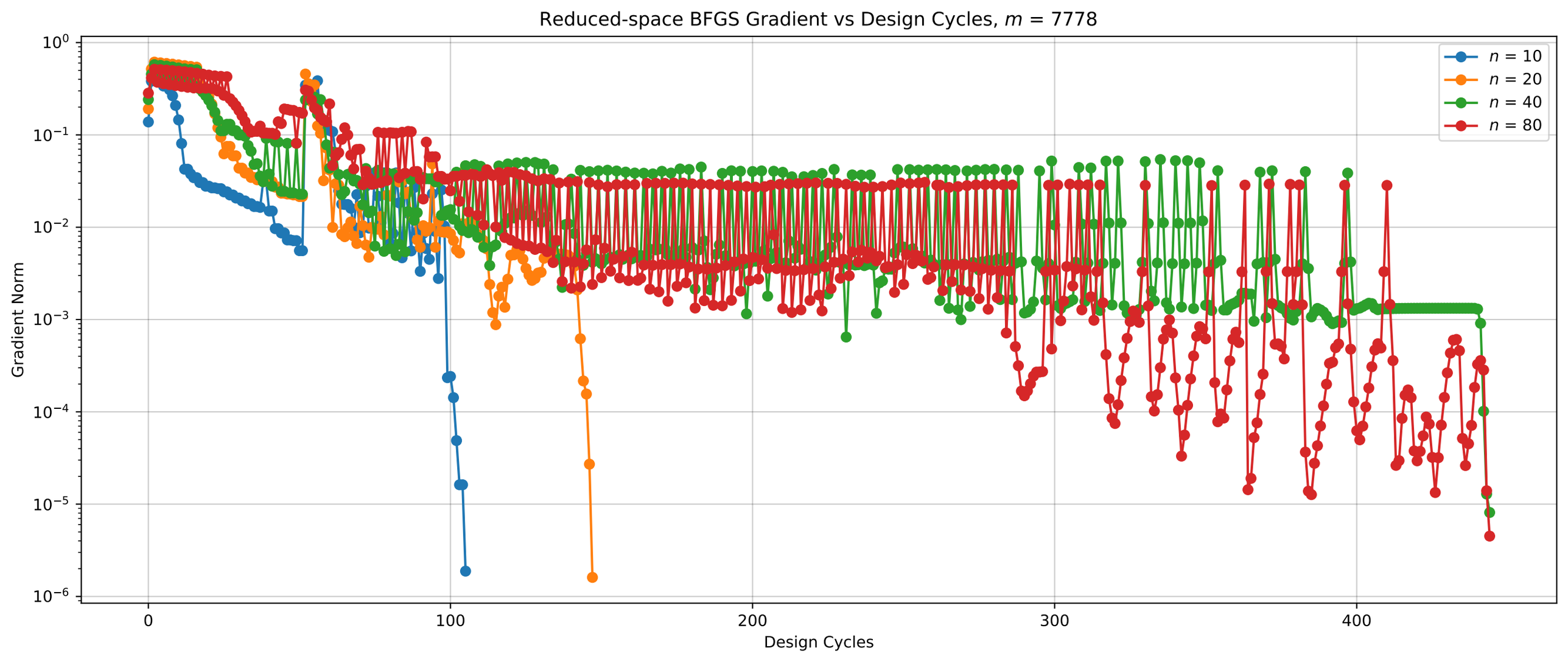
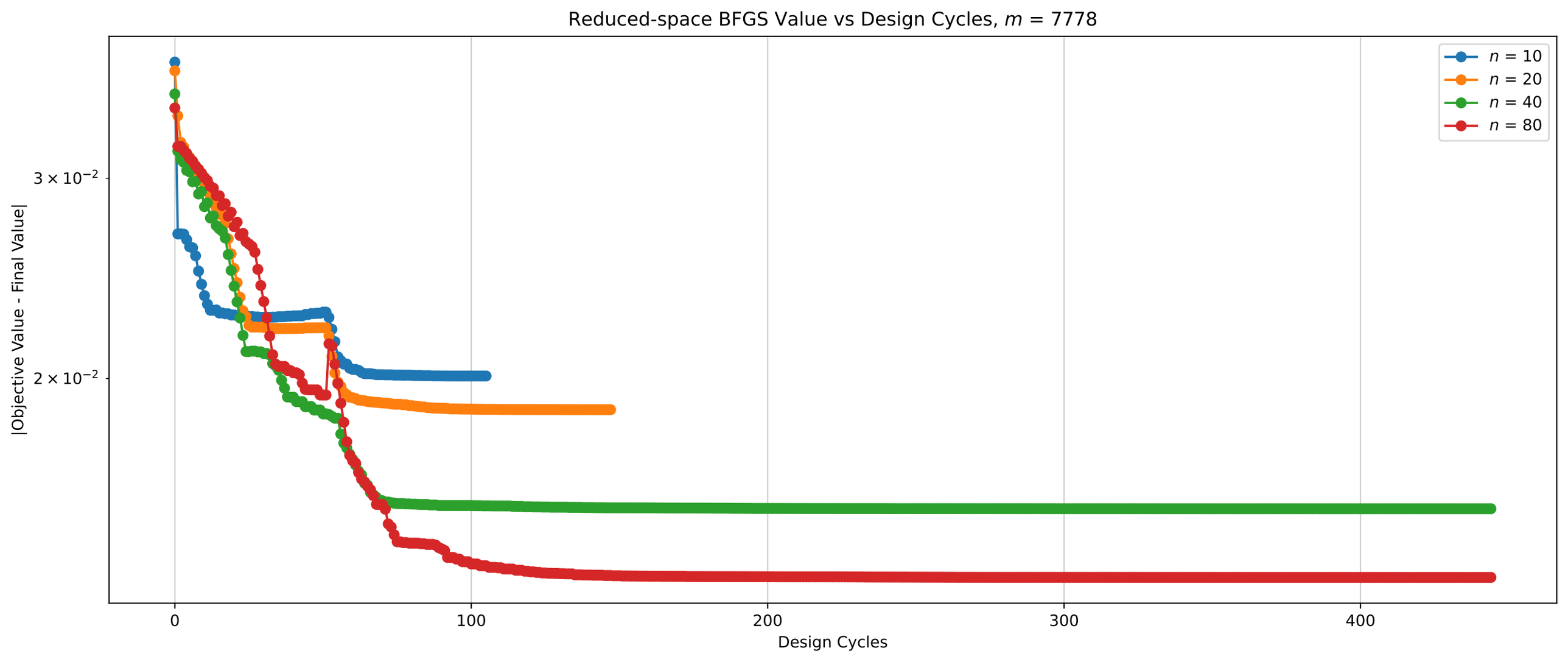

Reduced-space BFGS Gradient vs Design Cycles, m = 2594
Gradient Norm
Design Cycles
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
25
50
75
100
125
150
175
n = 10
n = 20
n = 40
n = 80

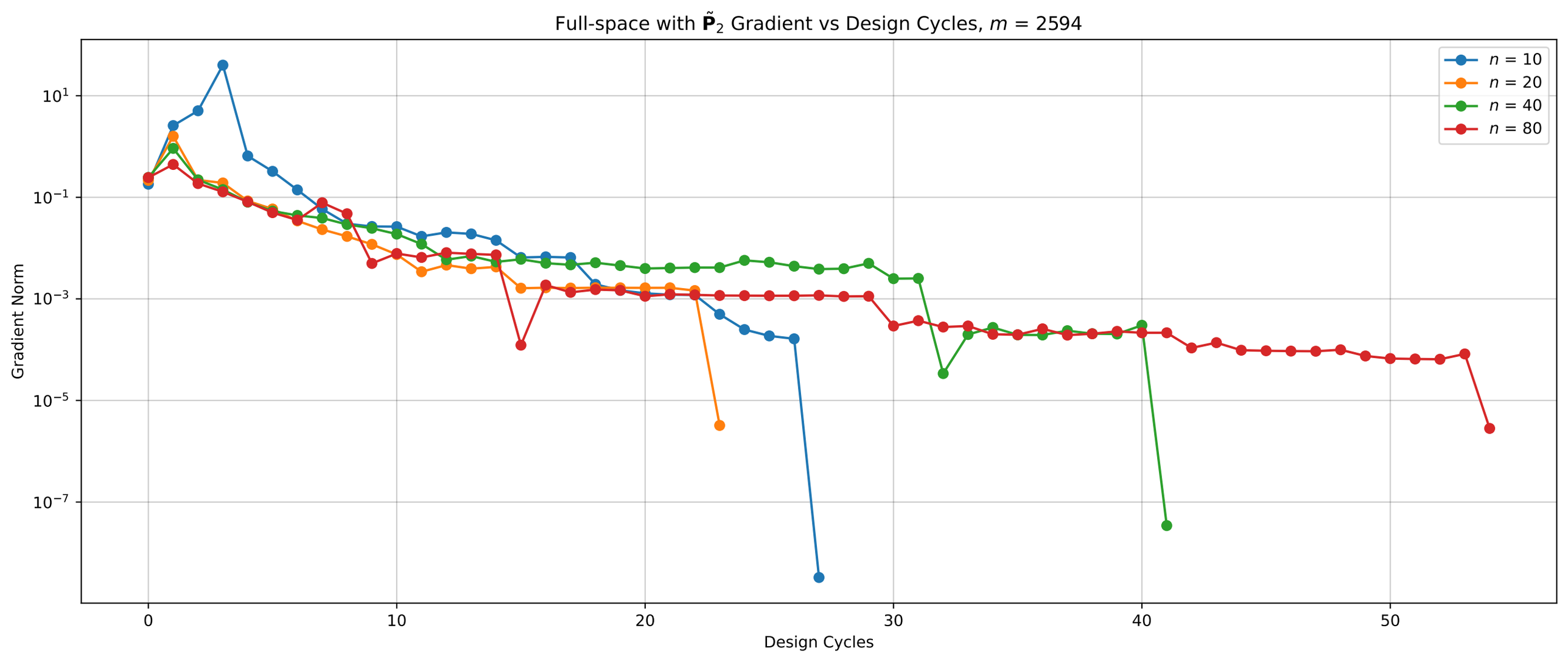

Reduced-space BFGS Value vs Design Cycles, m = 2594
n = 10
n = 20
n = 40
n = 80
|Objective Value - Final Value|
1.7×10^{-1}
1.65×10^{-1}
1.6×10^{-1}
1.55×10^{-1}
1.5×10^{-1}
1.45×10^{-1}
1.4×10^{-1}
1.35×10^{-1}
0
25
50
75
100
125
150
175
Design Cycles

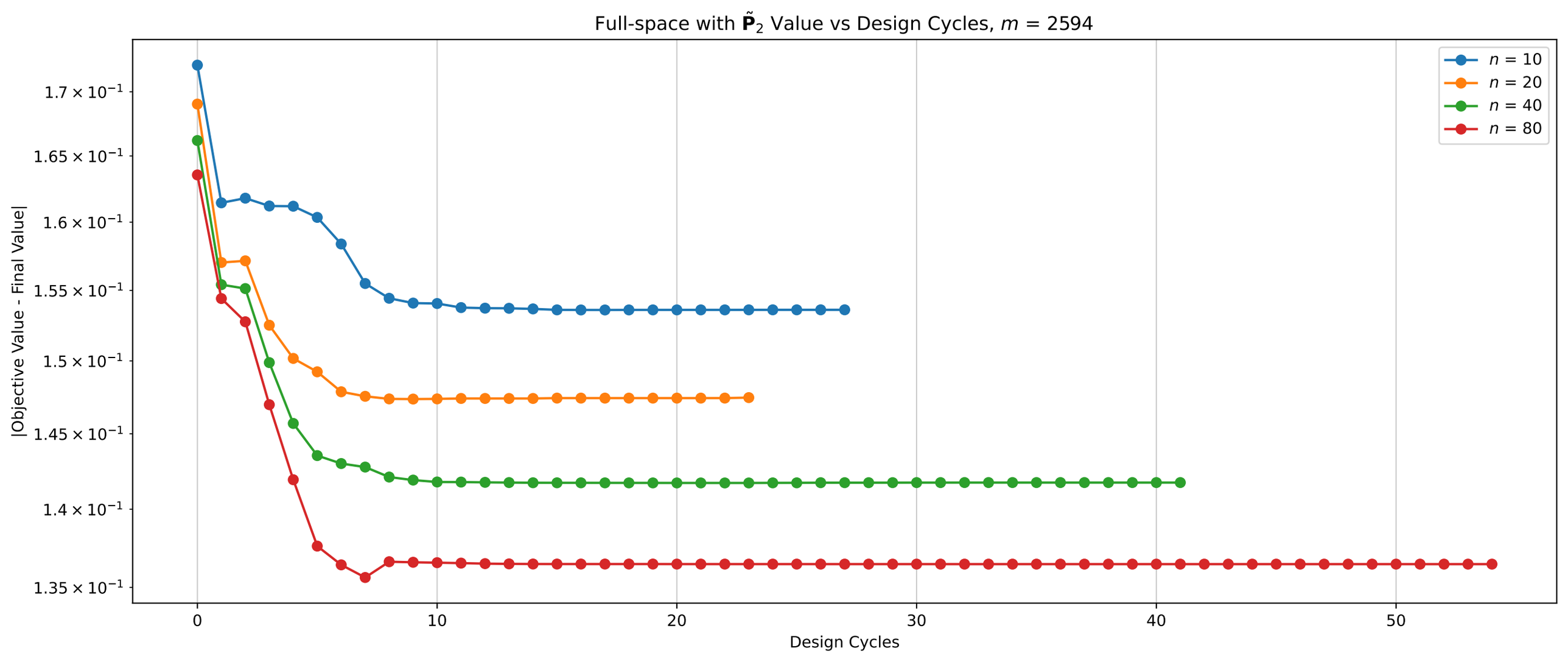

Reduced-space BFGS Gradient vs Design Cycles, m = 5186
Gradient Norm
Design Cycles
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
50
100
150
200
250
n = 10
n = 20
n = 40
n = 80

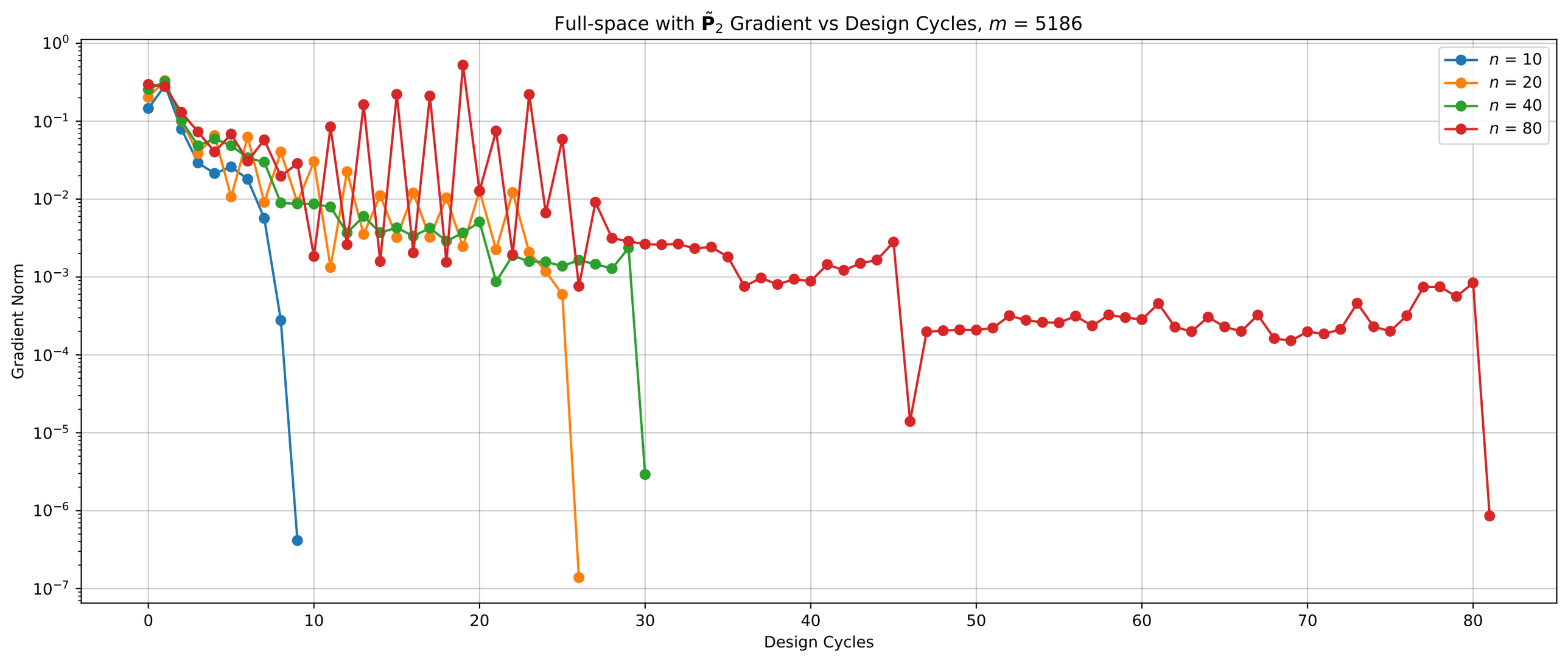

Reduced-space BFGS Value vs Design Cycles, m = 5186
n = 10
n = 20
n = 40
n = 80
6×10^{-2}
5×10^{-2}
4×10^{-2}
3×10^{-2}
|Objective Value - Final Value|
0
50
100
150
200
250
Design Cycles

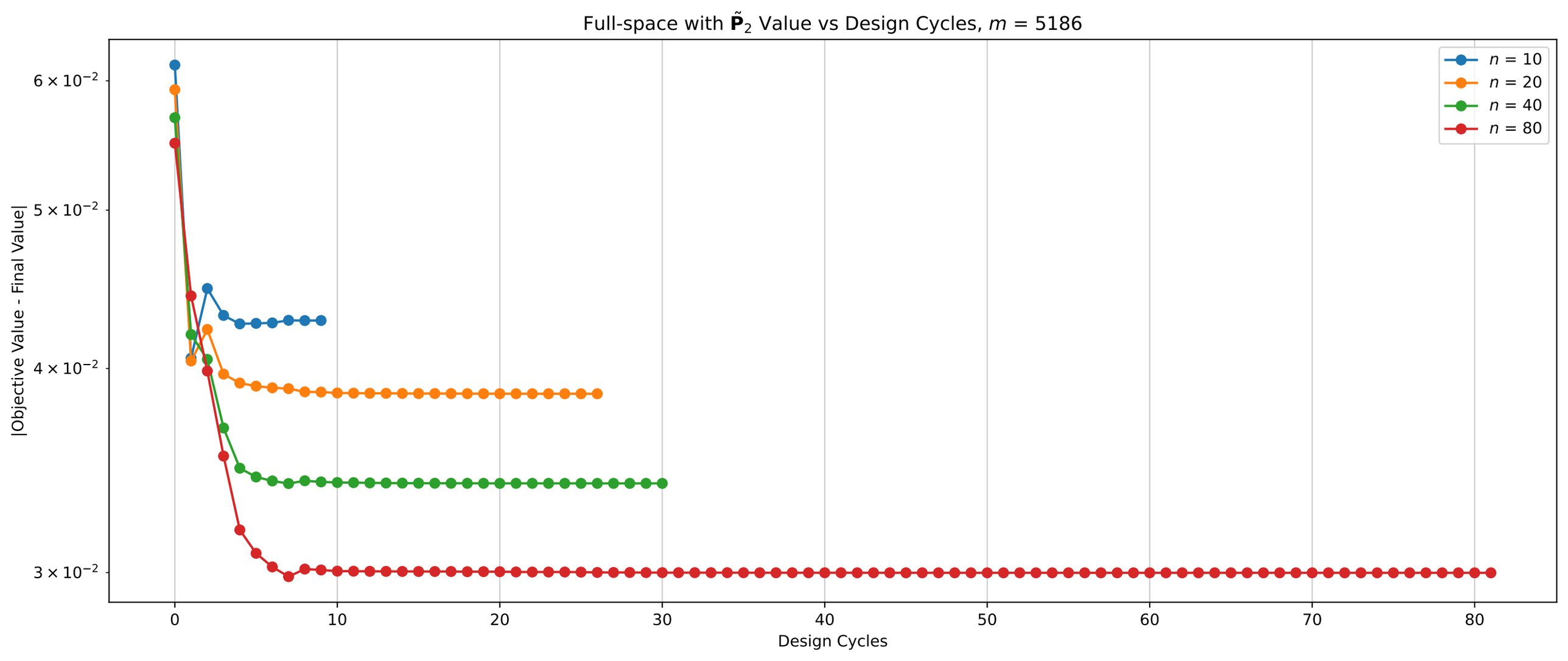

Reduced-space BFGS Gradient vs Design Cycles, m = 7778
Gradient Norm
Design Cycles
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0
100
200
300
400
n = 10
n = 20
n = 40
n = 80

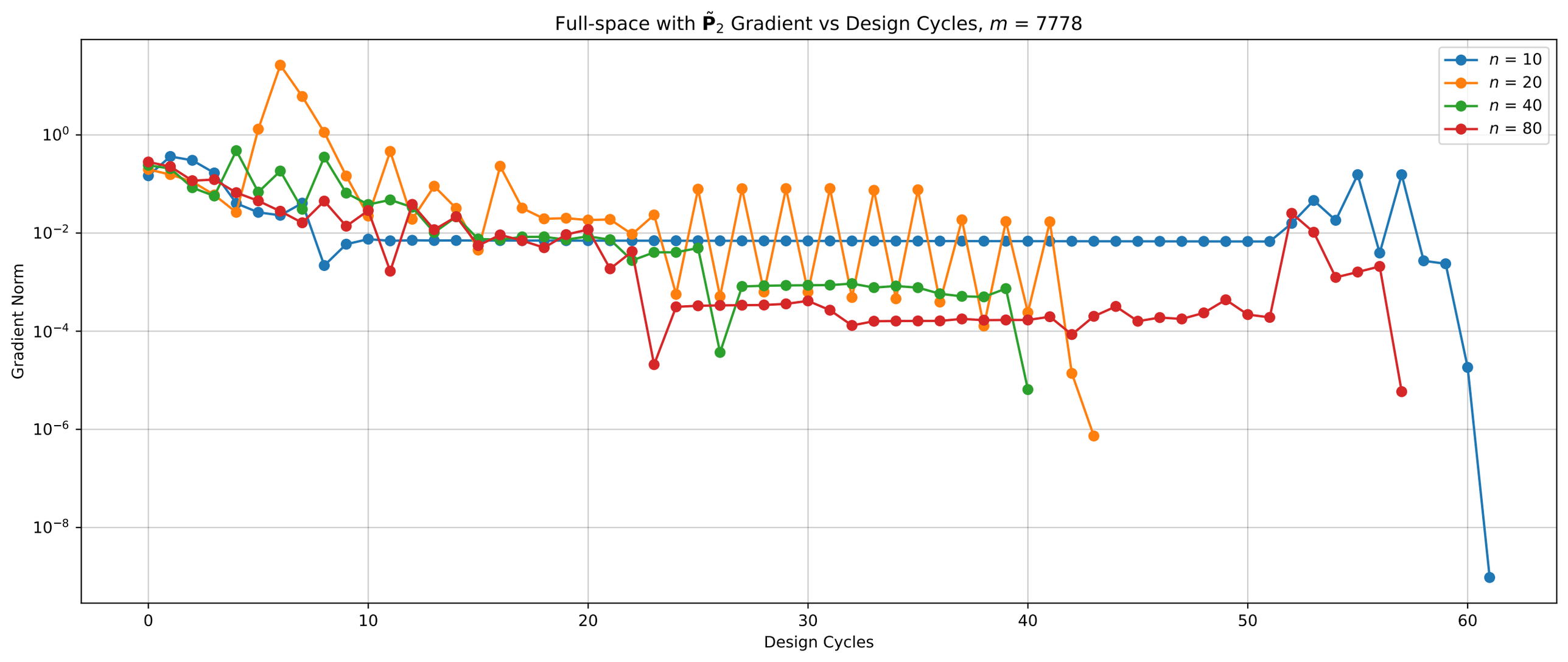

Reduced-space BFGS Value vs Design Cycles, m = 7778
n = 10
n = 20
n = 40
n = 80
3×10^{-2}
2×10^{-2}
|Objective Value - Final Value|
0
100
200
300
400
Design Cycles

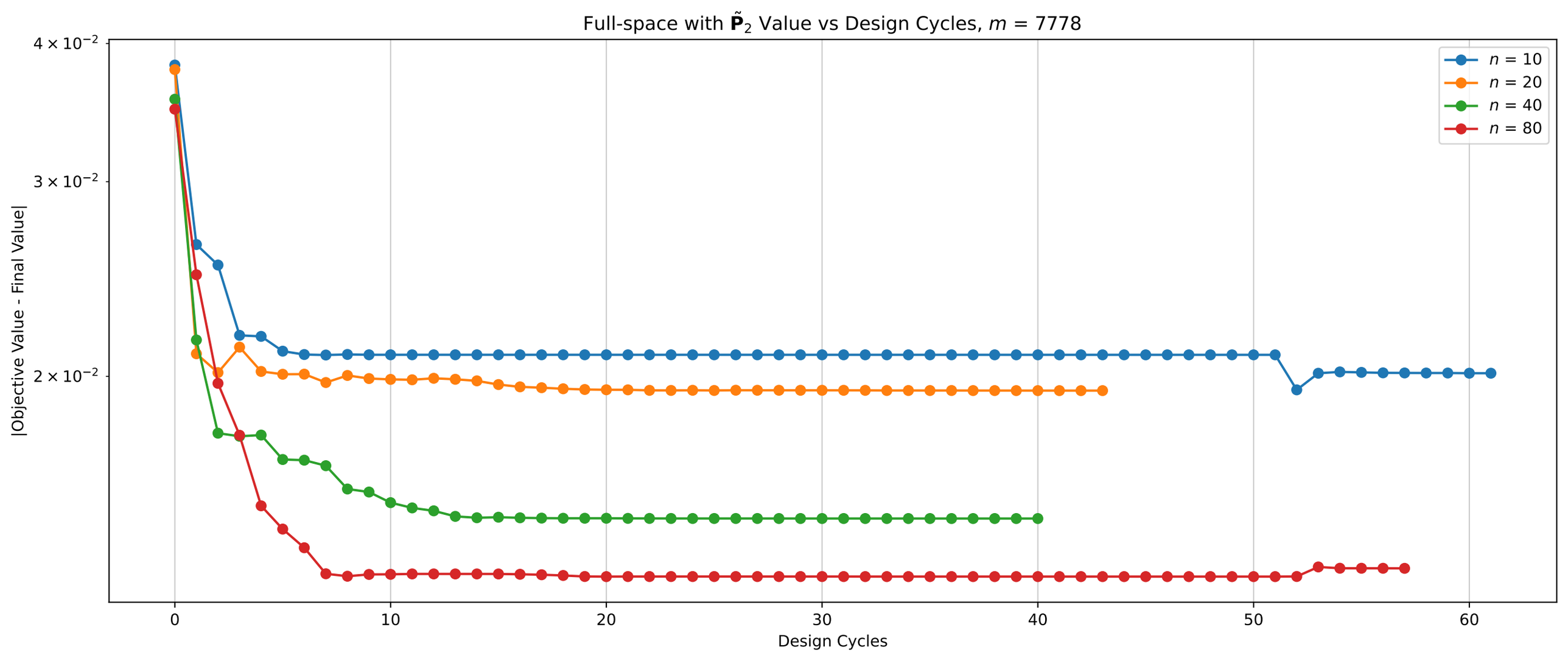

Full-space with $\tilde{\mathbf{P}}_2$ Gradient vs Design Cycles, m = 2594
Gradient Norm
Design Cycles
10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{-7}
0
10
20
30
40
50
n = 10
n = 20
n = 40
n = 80

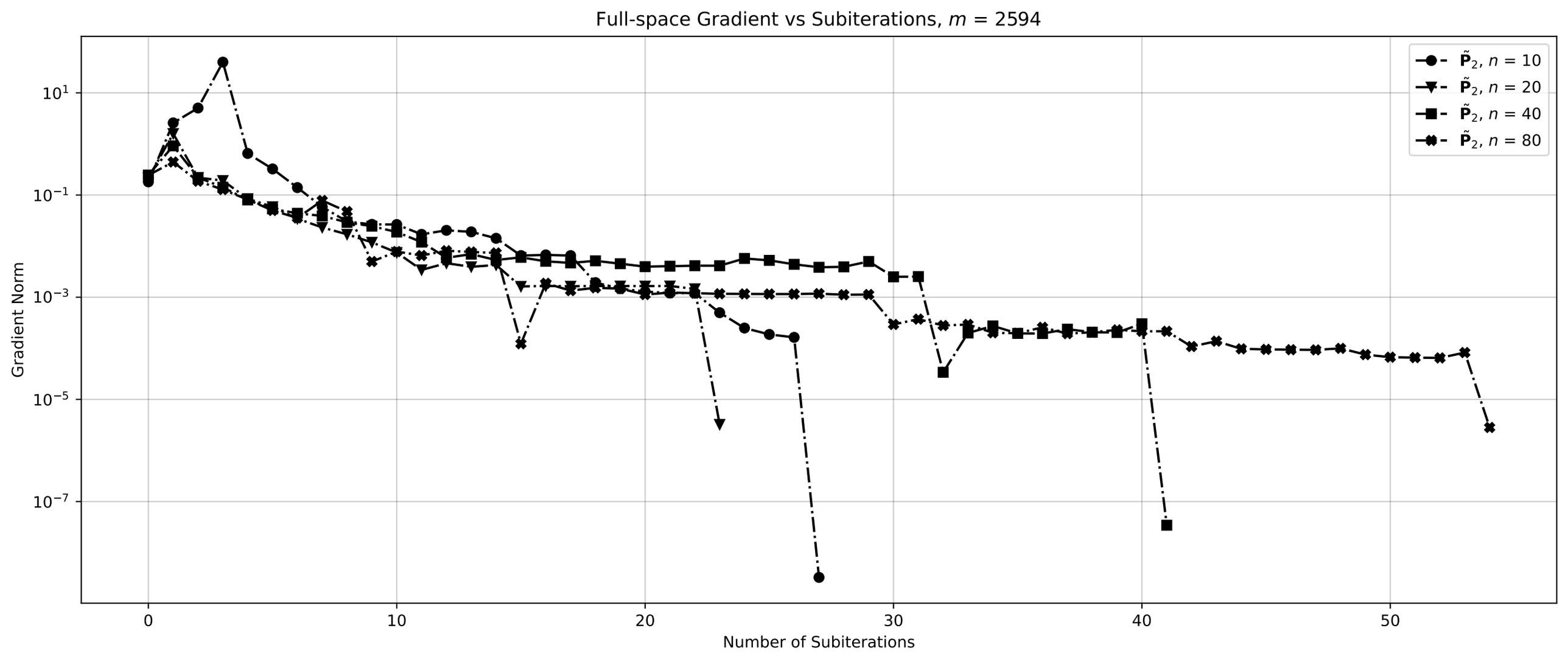

Full-space with $\tilde{\mathbf{P}}_2$ Value vs Design Cycles, m = 2594
|Objective Value - Final Value|
1.7×10^{-1}
1.65×10^{-1}
1.6×10^{-1}
1.55×10^{-1}
1.5×10^{-1}
1.45×10^{-1}
1.4×10^{-1}
1.35×10^{-1}
0
10
20
30
40
50
Design Cycles
n = 10
n = 20
n = 40
n = 80

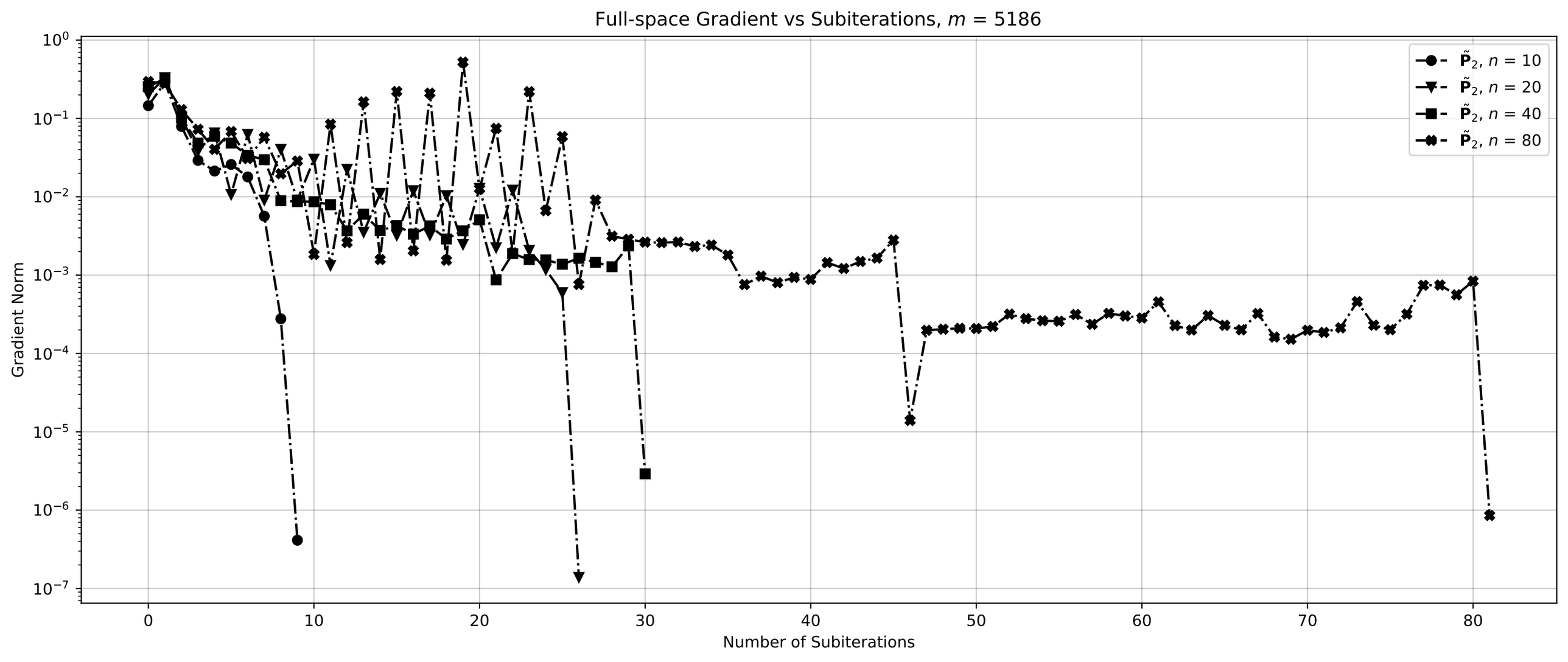

Full-space with $\tilde{\mathbf{P}}_2$ Gradient vs Design Cycles, m = 5186
Gradient Norm
Design Cycles
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
10
20
30
40
50
60
70
80
n = 10
n = 20
n = 40
n = 80

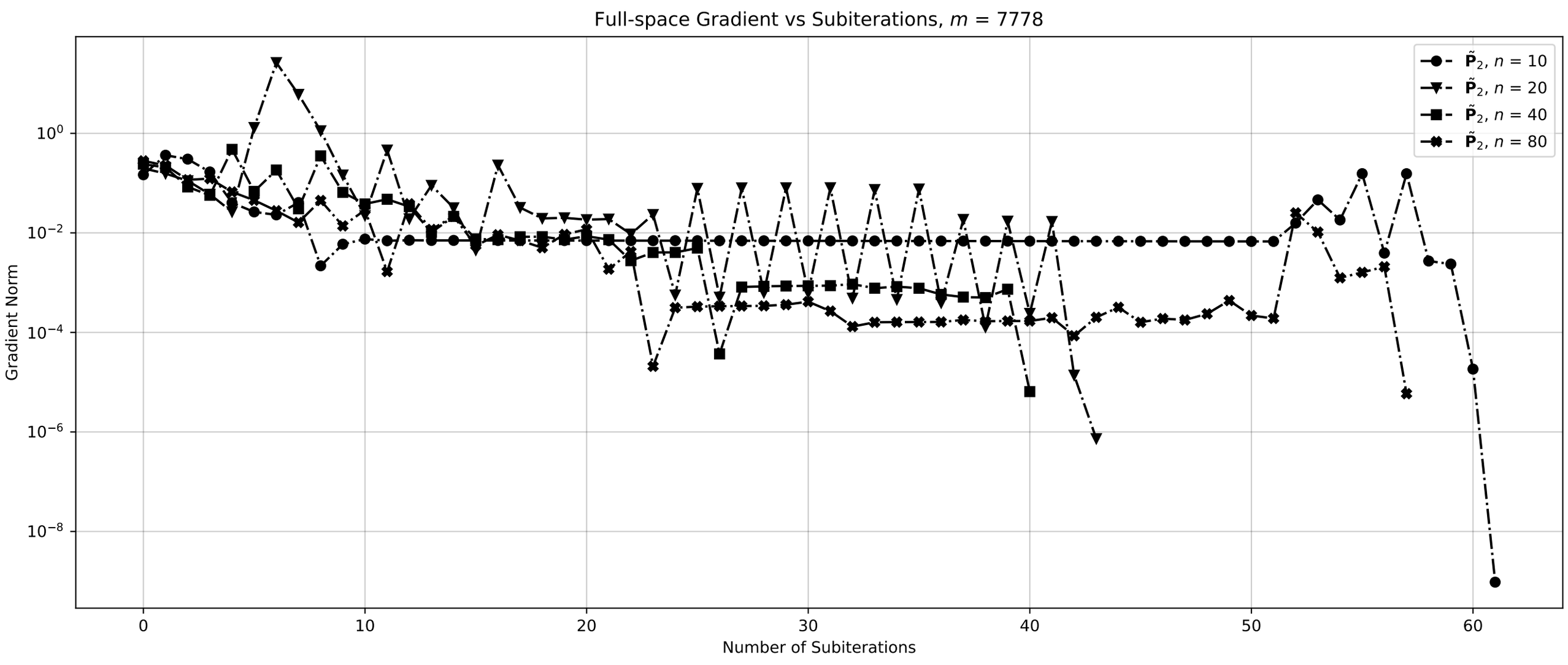

Full-space with $\tilde{\mathbf{P}}_2$ Value vs Design Cycles, m = 5186
|Objective Value - Final Value|
6×10^{-2}
5×10^{-2}
4×10^{-2}
3×10^{-2}
0
10
20
30
40
50
60
70
80
Design Cycles
n = 10
n = 20
n = 40
n = 80


Full-space with $\tilde{\mathbf{P}}_2$ Gradient vs Design Cycles, m = 7778
n = 10
n = 20
n = 40
n = 80
Gradient Norm
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
0
10
20
30
40
50
60
Design Cycles


Full-space with $\tilde{\mathbf{P}}_2$ Value vs Design Cycles, m = 7778
4×10^{-2}
3×10^{-2}
2×10^{-2}
|Objective Value - Final Value|
0
10
20
30
40
50
60
Design Cycles
n = 10
n = 20
n = 40
n = 80


Full-space Gradient vs Subiterations, m = 2594
Gradient Norm
Number of Subiterations
10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{-7}
0
10
20
30
40
50
$\tilde{\mathbf{P}}_2$, n = 10
$\tilde{\mathbf{P}}_2$, n = 20
$\tilde{\mathbf{P}}_2$, n = 40
$\tilde{\mathbf{P}}_2$, n = 80


Full-space Gradient vs Subiterations, m = 5186
Gradient Norm
Number of Subiterations
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
10
20
30
40
50
60
70
80
$\tilde{\mathbf{P}}_2$, n = 10
$\tilde{\mathbf{P}}_2$, n = 20
$\tilde{\mathbf{P}}_2$, n = 40
$\tilde{\mathbf{P}}_2$, n = 80


Full-space Gradient vs Subiterations, m = 7778
$\tilde{\mathbf{P}}_2$, n = 10
$\tilde{\mathbf{P}}_2$, n = 20
$\tilde{\mathbf{P}}_2$, n = 40
$\tilde{\mathbf{P}}_2$, n = 80
Gradient Norm
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
0
10
20
30
40
50
60
Number of Subiterations

Full-space Gradient vs Subiterations

m = 2594

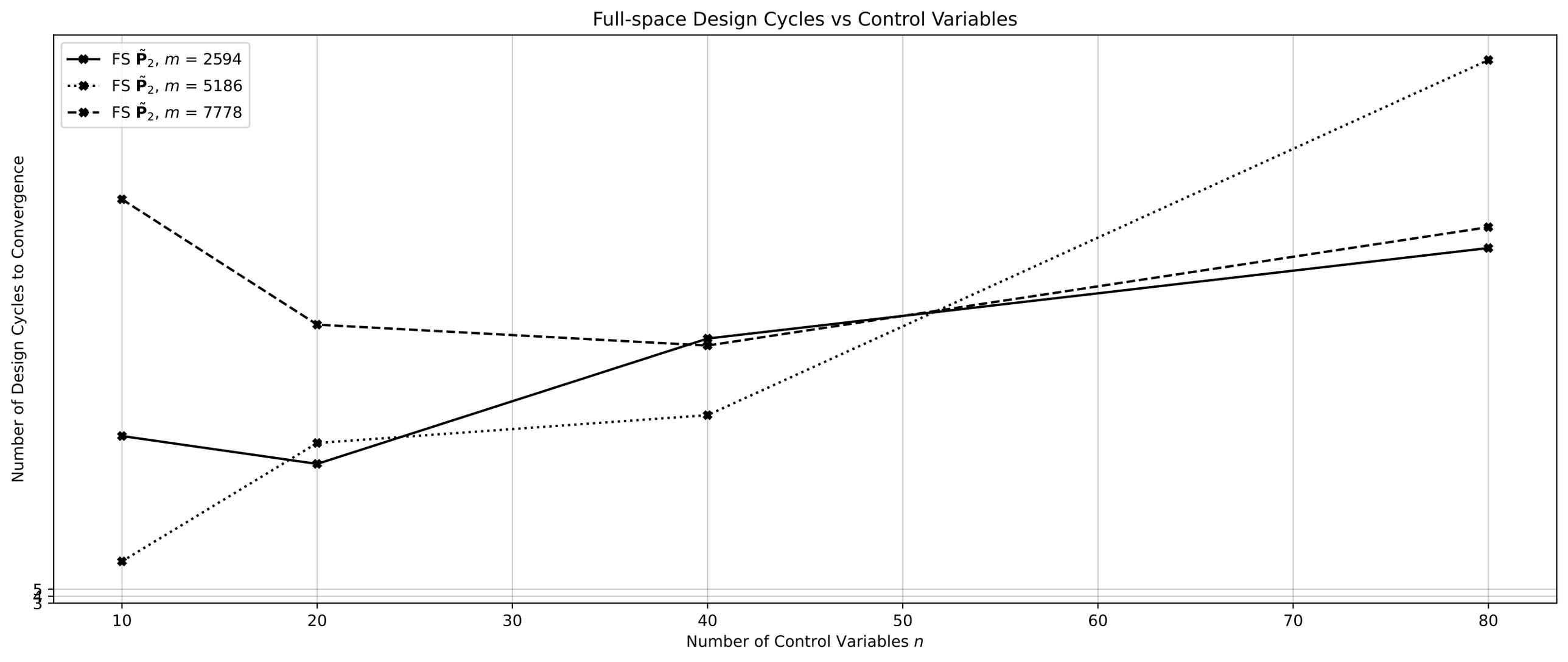
m = 5186

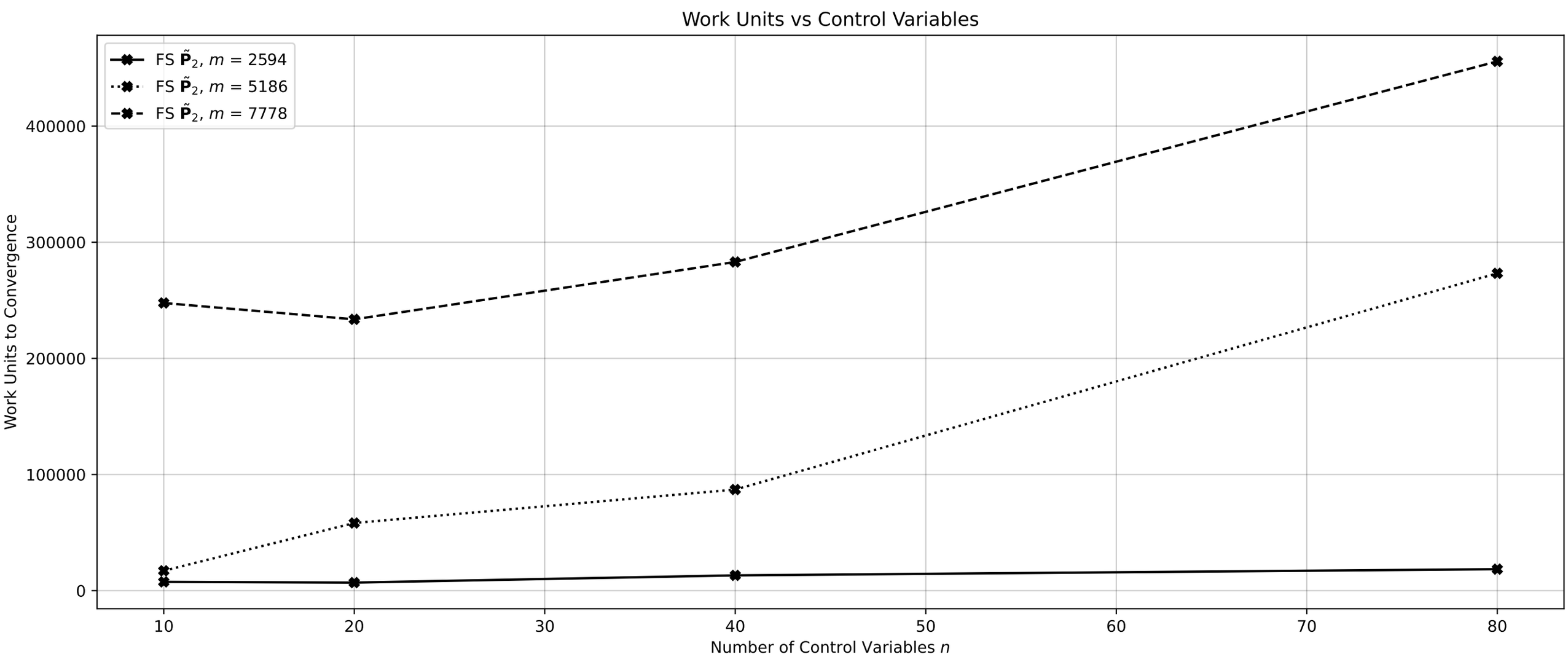
m = 7778

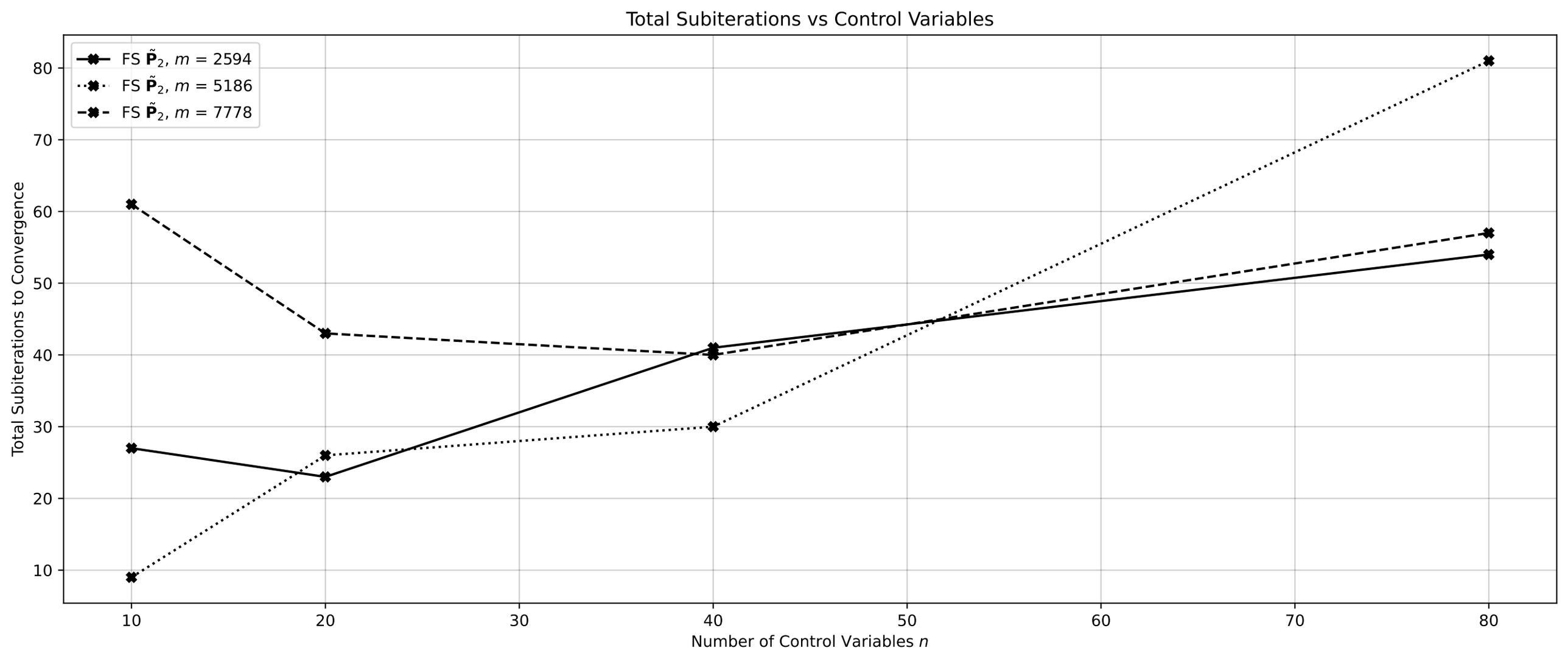
Gradient Norm

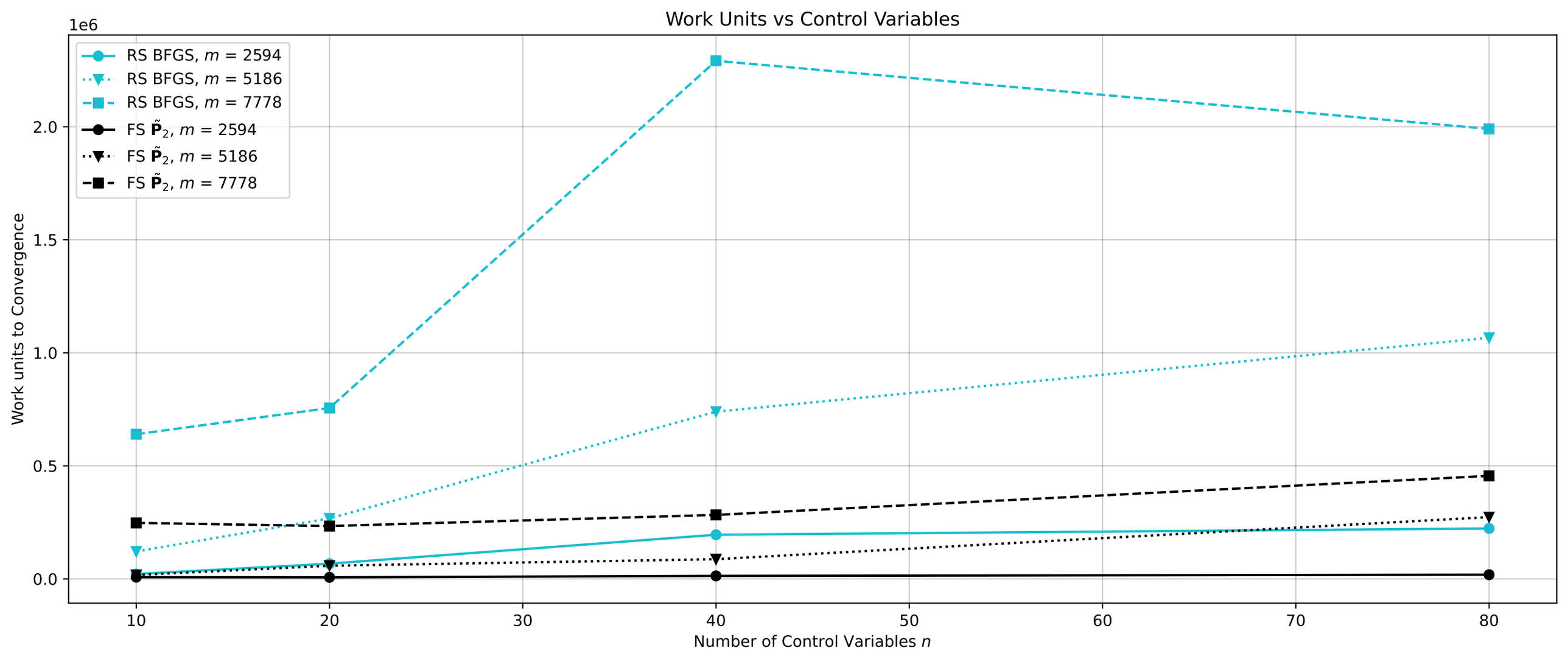
Number of subiterations

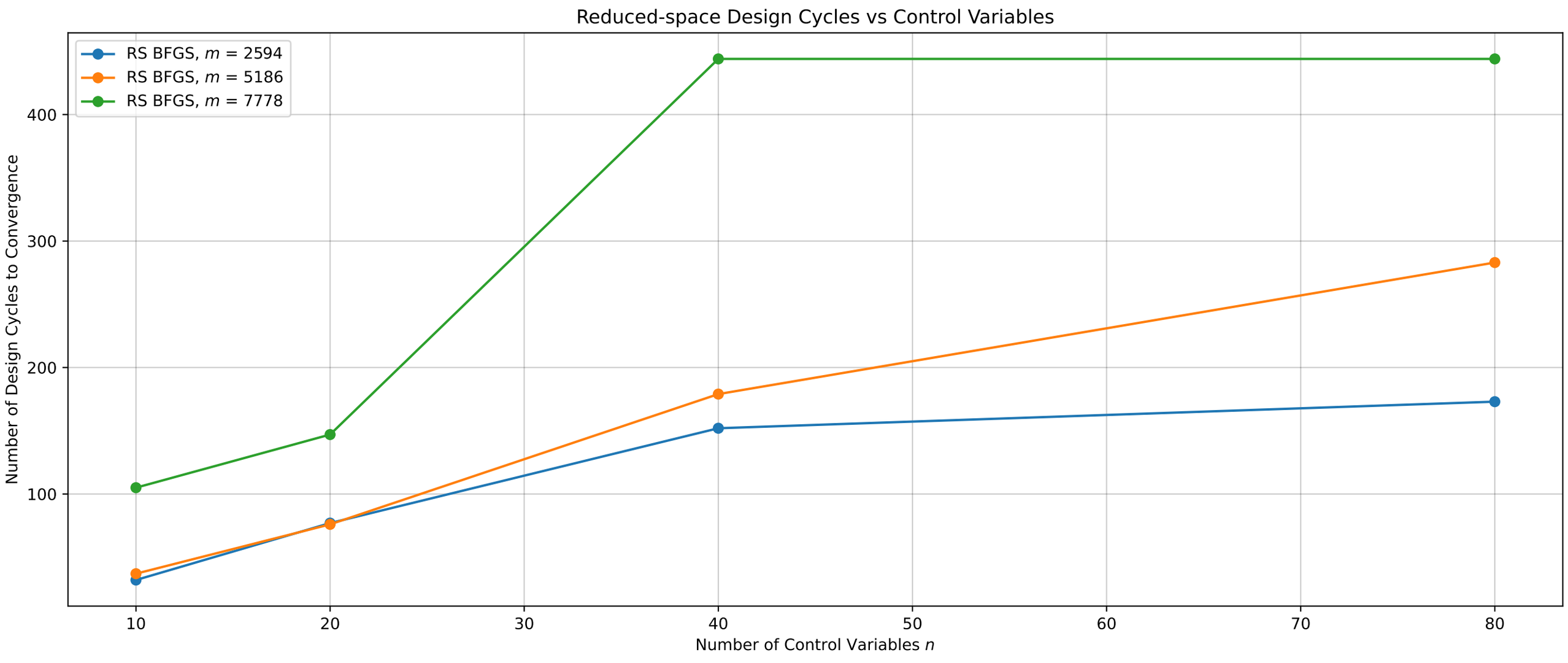
$\tilde{\mathbf{P}}_2$, n = 10
$\tilde{\mathbf{P}}_2$, n = 20
$\tilde{\mathbf{P}}_2$, n = 40
$\tilde{\mathbf{P}}_2$, n = 80


Full-space Design Cycles vs Control Variables
FS $\tilde{\mathbf{P}}_2$, m = 2594
FS $\tilde{\mathbf{P}}_2$, m = 5186
FS $\tilde{\mathbf{P}}_2$, m = 7778
Number of Design Cycles to Convergence
Number of Control Variables n
10
20
30
40
50
60
70
80


Work Units vs Control Variables
FS $\tilde{\mathbf{P}}_2$, $m = 2594$
FS $\tilde{\mathbf{P}}_2$, $m = 5186$
FS $\tilde{\mathbf{P}}_2$, $m = 7778$
Work Units to Convergence
0
100000
200000
300000
400000
10
20
30
40
50
60
70
80
Number of Control Variables n


Total Subiterations vs Control Variables
FS $\tilde{\mathbf{P}}_2$, $m = 2594$
FS $\tilde{\mathbf{P}}_2$, $m = 5186$
FS $\tilde{\mathbf{P}}_2$, $m = 7778$
Total Subiterations to Convergence
Number of Control Variables n
10
20
30
40
50
60
70
80


Work Units vs Control Variables
1e6
RS BFGS, m = 2594
RS BFGS, m = 5186
RS BFGS, m = 7778
FS $\tilde{\mathbf{P}}_2$, m = 2594
FS $\tilde{\mathbf{P}}_2$, m = 5186
FS $\tilde{\mathbf{P}}_2$, m = 7778
Work units to Convergence
0.0
0.5
1.0
1.5
2.0
10
20
30
40
50
60
70
80
Number of Control Variables n


Reduced-space Design Cycles vs Control Variables
RS BFGS, m = 2594
RS BFGS, m = 5186
RS BFGS, m = 7778
Number of Design Cycles to Convergence
100
200
300
400
10
20
30
40
50
60
70
80
Number of Control Variables n

Reduced-space Gradient vs Design Cycles

m = 2594

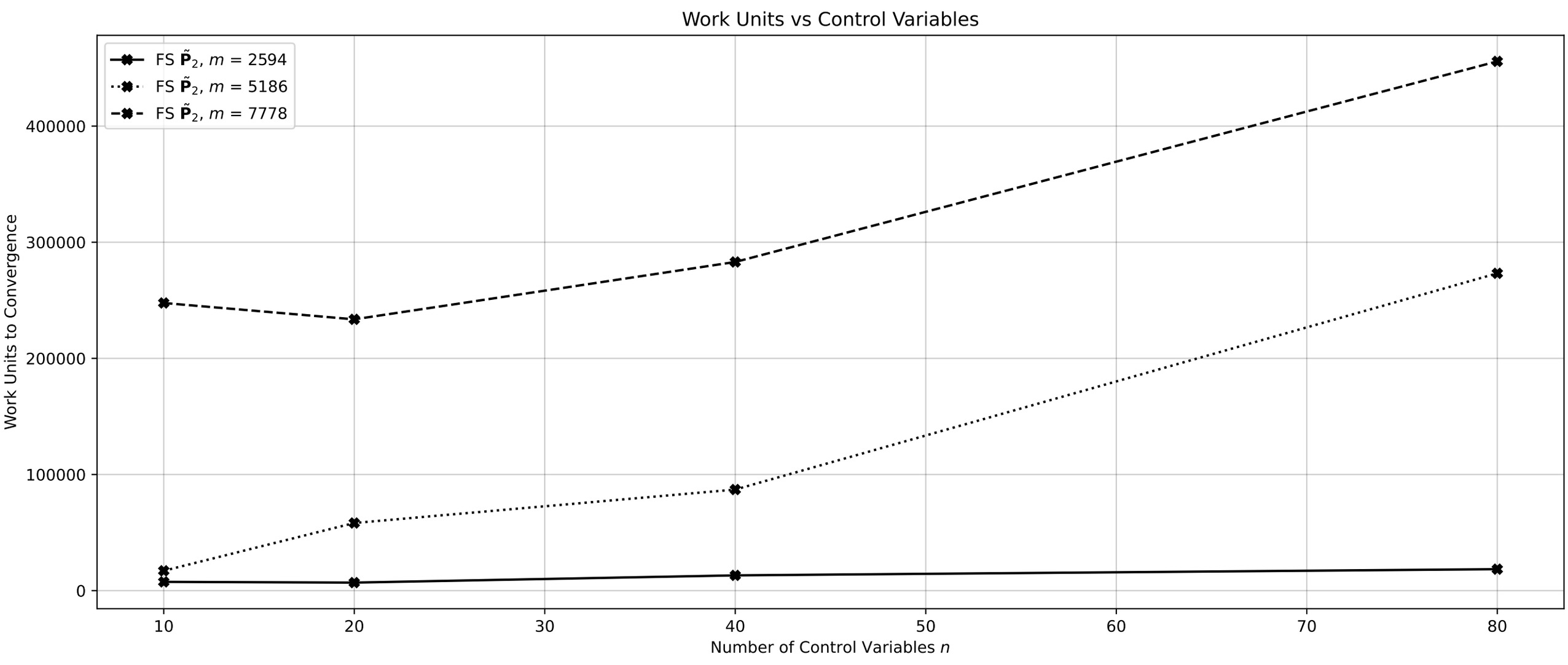
m = 5186

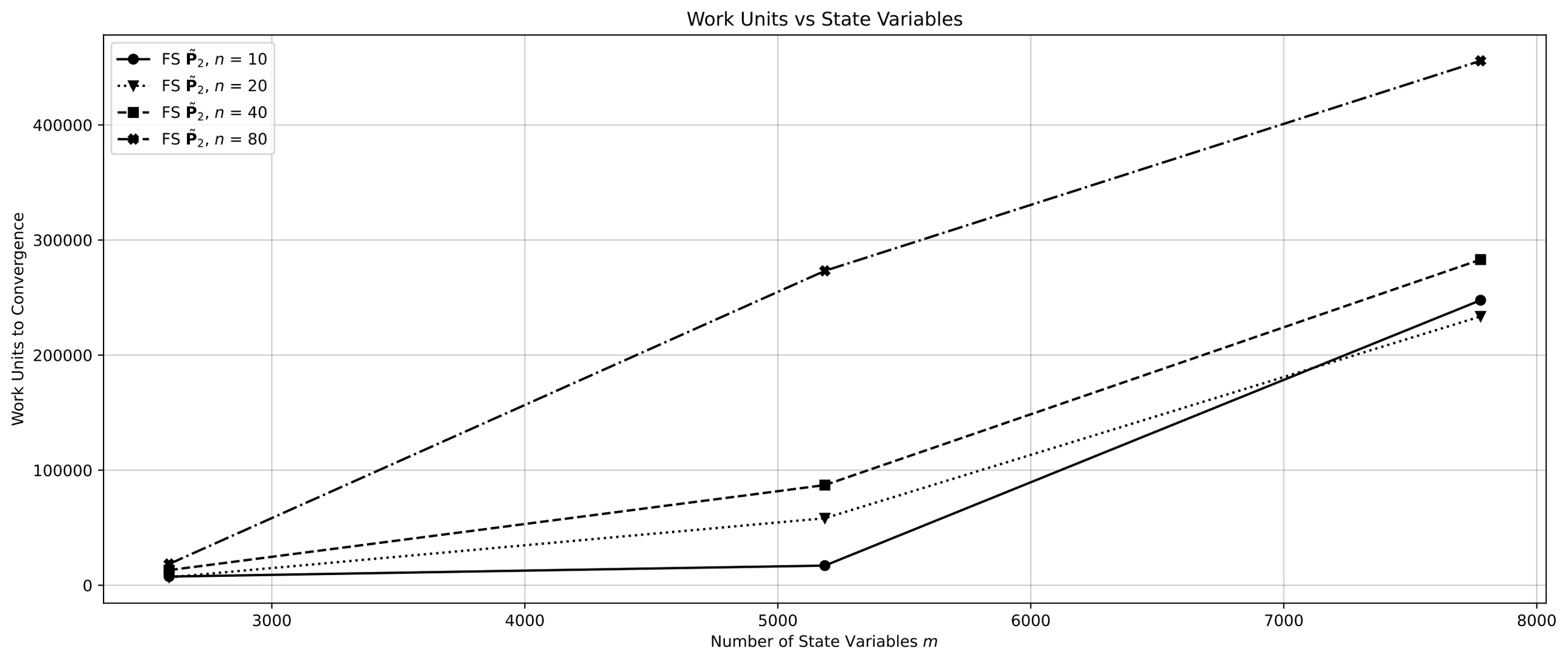
m = 7778

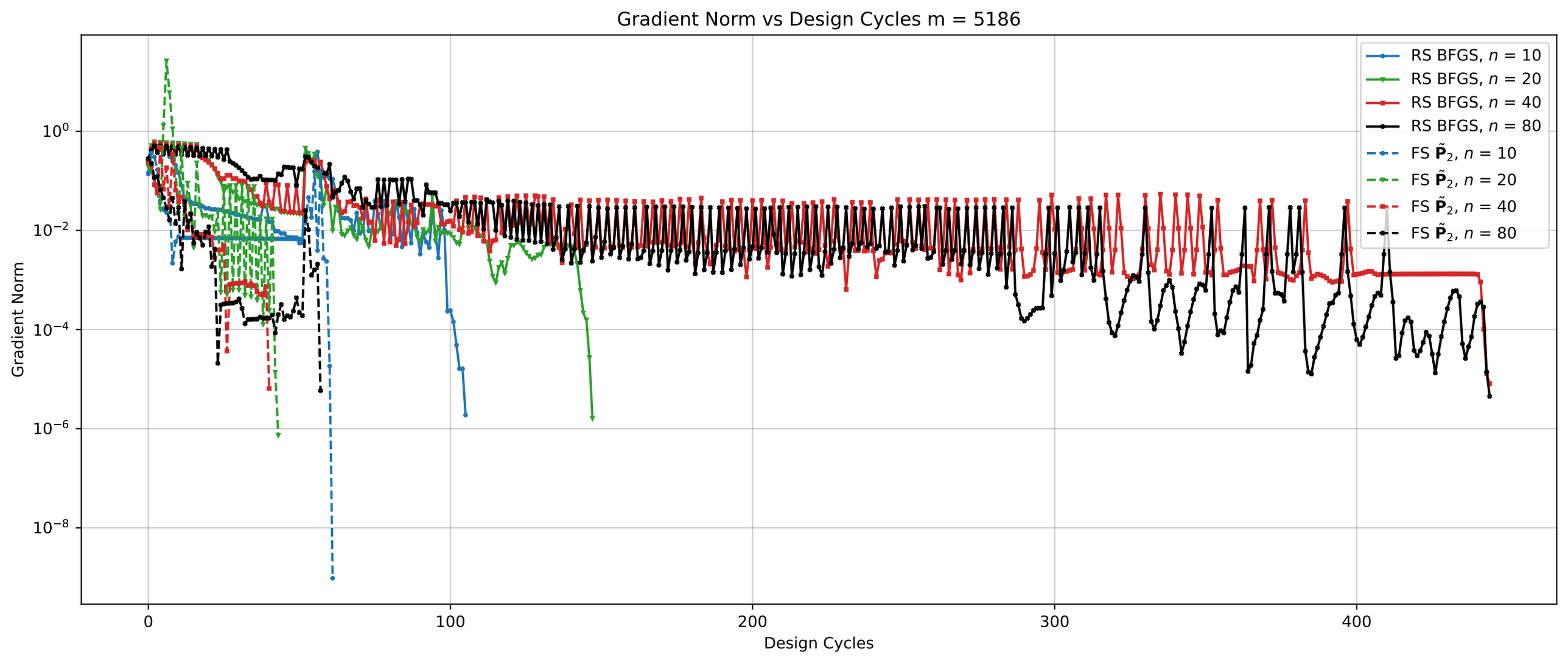
Gradient Norm

Design Cycles

0.0 0.2 0.4 0.6 0.8 1.0


Work Units vs Control Variables
FS $\tilde{\mathbf{P}}_2$, $m = 2594$
FS $\tilde{\mathbf{P}}_2$, $m = 5186$
FS $\tilde{\mathbf{P}}_2$, $m = 7778$
Work Units to Convergence
0
100000
200000
300000
400000
10
20
30
40
50
60
70
80
Number of Control Variables n


Work Units vs State Variables
FS $\tilde{\mathbf{P}}_2$, $n = 10$
FS $\tilde{\mathbf{P}}_2$, $n = 20$
FS $\tilde{\mathbf{P}}_2$, $n = 40$
FS $\tilde{\mathbf{P}}_2$, $n = 80$
Work Units to Convergence
0
100000
200000
300000
400000
3000
4000
5000
6000
7000
8000
Number of State Variables m


Gradient Norm vs Design Cycles m = 5186
Gradient Norm
Design Cycles
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
0
100
200
300
400
RS BFGS, n = 10
RS BFGS, n = 20
RS BFGS, n = 40
RS BFGS, n = 80
FS $\tilde{\mathbf{P}}_2$, n = 10
FS $\tilde{\mathbf{P}}_2$, n = 20
FS $\tilde{\mathbf{P}}_2$, n = 40
FS $\tilde{\mathbf{P}}_2$, n = 80